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Stochastic Modeling for Water Quality Management

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16. Abstract Because water pollution is a stochastic process, water quality standards must incorporate variability. After reviewing previous deterministic models, this document generalized and extended earlier stochastic models. In particular, the project expanded and verified the Custer and Krutchkoff model. The specific objectives were to: a) adapt the model to accept variable or random input loadings; b) to adapt the estuary model to treat segmented estuaries; c) to verify the adapted models with data supplied by WQO; d) to find a method for using data to estimate and predict the stochastic parameter Δ . The objectives were successfully achieved and verification accomplished with data from the Ohio River and the Potomac Estuary. The report concluded that the extended Stochastic Model can handle load inputs, rate constants, velocity, temperature, benthic demands, land runoff, hydraulic parameters, geometry, and random pollution inputs. It can accurately predict the time-dependent mean concentration in a transient state condition or pseudo-steady state condition at any point in a stream or estuary. Further, the proportion of time that the BOD, DO and nitrogen concentrations will be above or below any given level can also be predicted accurately. Recommendations were made for further use and expansion of the model.				
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***Stochastic Modeling for
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by

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for the
ENVIRONMENTAL PROTECTION AGENCY

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ABSTRACT

The purpose of this work was to extend and generalize the stochastic models found in: A Stochastic Model for Streams, by Thayer and Krutchkoff, ASCE J. Sanitary Engineering Division No. SA3, June 1967, pp. 59-72, Generalized Initial Conditions for the Stochastic Model for Pollution and Dissolved Oxygen in Streams, by Moushegian and Krutchkoff, Water Resources Research Center of Virginia, Bulletin 28, August 1969, and Stochastic Model for BOD and DO in Estuaries, by Custer and Krutchkoff, ASCE J. Sanitary Engineering Division, October 1969, pp. 865-885. (In particular there were four tasks: a) to adapt the models to accept variable or random input loads, b) to adapt the estuary model to treat segmented estuaries, c) to verify the adapted models with data supplied by WQO, d) to find a method for using data to estimate and predict the stochastic parameter Δ).

The four tasks were successfully completed. Verification was done with data from the Ohio River and from the Potomac Estuary.

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INTRODUCTION

WHY A STOCHASTIC MODEL

Pollution is a Stochastic Process. That is, one cannot predict exactly how much pollution there will be at any given time and place in a stream or estuary. One has simply to look at stream or estuary data to observe this unpredictable fluctuation. Unfortunately stream quality standards are given in absolute terms. It is, however, unreasonable to expect even a clean stream to have Dissolved Oxygen (DO) readings above a preset value all the time. Natural fluctuation might take the DO reading below any value for brief periods. This momentary violation of a standard can cause no ill effects. In an attempt to be realistic one might interpret the standard to mean that the average value must be above the standard. This too causes problems. A high average DO might be the result of an unnecessarily high DO concentration part of the time and a dangerously low DO concentration the remainder of the time. Fish kills often occur when the average DO is above the prescribed value.

The only solution to this problem is to consider variability as an important aspect of water pollution and incorporate it into water quality standards.

A good stochastic model can predict not only the average concentration of a pollutant and the associated DO but also the variability of the pollutant or the DO concentration about its average value. In particular it should be able to predict accurately the proportion of the time that the pollutant will be above any given concentration level or the proportion of the time that DO will be below any given concentration level. Standards could then be written in terms more appropriate to their purpose. If, for example, the purpose were to prevent fish kills the standard might allow fluctuation in DO such that there is no less than 4 ppm DO 50% of the time, no less than 3 ppm DO 20% of the time and no less than 2 ppm DO 5% of the time.

DETERMINISTIC MODELS

STREETER-PHELPS MODEL

Streeter and Phelps [68] assumed that the dissolved oxygen concentrations in a stream are governed by two independent reactions. First, the oxygen is depleted by the bacteria while stabilizing the organic matter. Secondly, the DO is replenished by absorption at the surface from the atmosphere. By definition the Biochemical Oxygen Demand (BOD) is decreased by the first mechanism at the same rate the DO is depleted. They assumed both of these reactions to be first order. The BOD and DO are decreased at a rate proportional to the remaining BOD, and the DO is increased at a rate proportional to the oxygen deficit (OD). This leads to the following differential equations:

$$dL/dt = -K_1 L, \quad (1)$$

and

$$dD/dt = -K_2 D + K_1 L, \quad (2)$$

where

t is the time of reaction,

L is the BOD level,

D is the oxygen deficit level

K_1 is the coefficient defining the rate of deoxygenation,
and

K_2 is the coefficient defining the rate of reaeration.

Initial conditions $L = L_0$ and $D = D_0$ at $t = 0$ are imposed. The differential equations have solutions

$$L = L_0 e^{-K_1 t}, \quad (3)$$

$$D = \frac{K_1 L_0}{K_2 - K_1} (e^{-K_1 t} - e^{-K_2 t}) + D_0 e^{-K_2 t} \quad (4)$$

The independent variable in (3) and (4) is reaction time, i.e., these equations characterize a static situation such as polluted water in a laboratory beaker. In order to apply the equation to a stream it is necessary to make certain assumptions about the flow. It is assumed that the system is uniform and steady state and there is no longitudinal dispersion. The last assumption implies that in any cross-section the pollution remains intact, not spilling over into neighboring cross-sections as it moves down stream.

Under these assumptions reaction time is equivalent to travel time. If the uniform velocity is given by

$$U = dx/dt, \quad (5)$$

then

$$x = Ut \quad (6)$$

Where $x = 0$ corresponds to $t = 0$. With this transformation of the independent variable the pollution and DO levels can be obtained from equations (3) and (4) for any point down stream from $x = 0$.

DOBBINS' MODEL

W. E. Dobbins [18] modified and extended the Streeter-Phelps equations, taking into account various additional sources of oxygen supply and demand. Streeter and Phelps assumed that the only reactions in a stream were the bacterial deoxygenation and reaeration. Dobbins states additional processes which may take place in a particular stretch of the stream.

1. The removal of BOD by sedimentation or absorption.
2. The addition of BOD along the stretch by the scour of bottom deposits or by the diffusion of partially decomposed organic products from the benthal layer into the water above.
3. The addition of BOD along the stretch by the local runoff.
4. The removal of oxygen from the water by diffusion into the benthal layer to satisfy the oxygen demand in the aerobic zone of this layer.
5. The removal of oxygen from the water by purging action of gases rising from the benthal layer.
6. The addition of oxygen by photosynthetic action of plankton and fixed plants.
7. The removal of oxygen by the respiration of plankton and fixed plants.
8. The continuous redistribution of both BOD and oxygen by the effect of longitudinal dispersion.

Dobbins states equations for BOD and DO concentrations without derivation. A heuristic development of the equations is given by Pyatt [64]; O'Connor [59] gives

a somewhat more rigid development. The following is a non-rigid outline of the derivation.

Suppose that the concentration of a substance is a function of the spatial parameter x and the temporal parameter t . Let $c(x,t)$ represent the concentration function. Then by definition

$$dc = \frac{\partial c}{\partial x} dx + \frac{\partial c}{\partial t} dt, \quad (7)$$

or

$$\frac{dc}{dt} = \frac{\partial c}{\partial x} \frac{dx}{dt} + \frac{\partial c}{\partial t}. \quad (8)$$

Letting $U = dx/dt$ represent the longitudinal velocity, one obtains

$$\frac{dc}{dt} = U \frac{\partial c}{\partial x} + \frac{\partial c}{\partial t}. \quad (9)$$

dc/dt represents the total change in concentration in time. The total change can be divided into two components; the gain or loss of concentration by diffusion, and the gain or loss of concentration via the local sources and sinks. The change in concentration due to the sources and sinks can be represented by $\sum S$. The diffusion term is of the Fickian type, which represents diffusion as proportional to the change in the concentration gradient, i.e., $E \partial^2 c / \partial x^2$ where E is defined to be the diffusion coefficient. Therefore equation (9) becomes

$$\frac{\partial c}{\partial t} = E \frac{\partial^2 c}{\partial x^2} - U \frac{\partial c}{\partial x} + \sum S. \quad (10)$$

Dobbins assumes the process for the stretch as a whole is a steady state process, the conditions in every cross-section being unchanged with time. Therefore, $c(x,t) = c(x)$ and $\partial c / \partial t = 0$. Thus

$$0 = E \frac{d^2 c}{dx^2} - U \frac{dc}{dx} + \sum S. \quad (11)$$

The characteristics of the sources and sinks are based on the following assumptions:

1. Bacterial deoxygenation and atmospheric reaeration are treated identically to the Streeter-Phelps model.
2. The removal of BOD by sedimentation, absorption,

and all other non-oxygen consuming processes is a first order reaction; the rate of removal being proportional to the amount present.

3. The removal of oxygen by the benthic demand and by plant respiration, the addition of oxygen by photosynthesis, and the addition of BOD from the benthic layer or the local runoff are all uniform along the stretch.

Therefore the sources and sinks for BOD are mathematically described as follows:

1. L_a , the uniform rate of which pollution is added by local runoff.
2. $K_1 L$, the rate at which pollution decreases due to bacterial action.
3. $K_3 L$, the rate at which pollution decreases due to all non-oxygen consuming processes.

Therefore, the pollution concentration L can be obtained from equation (11), yielding the following differential equation

$$0 = E \frac{d^2 L}{dx^2} - U \frac{dL}{dx} - (K_1 + K_3) L + L_a. \quad (12)$$

The sources and sinks of oxygen are as follows:

1. $K_2 D$, the rate at which oxygen increases due to reaeration. D is the oxygen deficit.
2. $K_1 L$, the rate at which oxygen decreases due to bacterial action.
3. D_b , the decrease in oxygen due to the benthic demand.

Therefore, the oxygen deficit equation obtained from (11) is given by:

$$0 = E \frac{d^2 D}{dx^2} - U \frac{dD}{dx} - K_2 D + K_1 L + D_b. \quad (13)$$

In the interest of clarity it is necessary to comment on several of the sources and sinks. The numbers in the following remarks refer to the list of additional processes Dobbins added to the Streeter and Phelps model. The K_3 term includes terms in 2 as well as 1. $K_3 L$, is the net effect of all of these processes, so K_3 may be positive or negative depending on the relative magnitudes

o. he processes. The benthic demand term D encompasses all the processes in 4 through 7. In order to include photosynthesis, it is necessary to consider the effect as uniform in time.

The rate of reduction of DO by the benthic demand is assumed to be independent of the oxygen level. Clearly this cannot be the case when DO is near zero, or negative oxygen concentration would result. In truth this assumption loses its validity for DO levels below 1 mg/l. As a precaution the analysis is restricted to situations where a minimum of 1 mg/l. of oxygen exists.

The longitudinal diffusion coefficient is in many cases uncertain. Dobbins calculated the amount of error which would be introduced if it were neglected. Using extreme values for the stream parameters he shows that the ratio of the true concentration to the concentration obtained by neglecting diffusion is 0.996. Lynch [54] later corrected this value to 0.960, i.e., an error of 4%. In any case, this represents the probable maximum error. Thus, the effect of longitudinal diffusion in a stream is negligible.

The solutions to (12) and (13) with $E = 0$ are

$$L = L_0 e^{-(K_1+K_3)t} + \frac{L_a}{K_1+K_3} (1 - e^{-(K_1+K_3)t}) \quad (14)$$

and

$$D = \frac{K_1}{K_2 - (K_1 + K_3)} \left(L_0 - \frac{L_a}{K_1 + K_3} \right) (e^{-(K_1 + K_3)t} - e^{-K_2 t}) + D_0 e^{-K_2 t} + \left(\frac{D_a}{K_2} + \frac{K_1 L_a}{K_2 (K_1 + K_3)} \right) (1 - e^{-K_2 t}). \quad (15)$$

where t is the travel time given by $t = x/U$, and the initial conditions are $L = L_0$ and $D = D_0$ at $t = 0$.

If all the parameters except K_1 and K_2 are set equal to zero. Equations (14) and (15) reduce to the Streeter-Phelps Equations (3) and (4).

O'CONNOR'S MODEL

Donald O'Connor [57,58,59] considered equations (12) and (13) for the estuary situation in which $E \neq 0$. The estuary is subdivided into sections in which conditions are assumed to be constant. The model then simulates concentrations averaged over the length of the individual sections and over the tidal cycle. Since the effect of tidal advection is not considered in the model, the value of the dispersion parameter E is increased to account for the apparent dispersion of the oscillating tidal flow as well as the dispersion due to turbulent diffusion.

THOMANN'S MODEL

Robert Thomann [73,74,76] has presented a systems analysis extension of the segment model of O'Connor. Physical, biological, etc., conditions within a segment of the estuary are assumed to be constant. The rate of change of concentration for a given component in the k th segment will depend on (a) the mass of that component transported from segment $k-1$ into k and from k into $k+1$; (b) dispersion from both $k-1$ and $k+1$ into k ; (c) the sources and sinks in segment k ; and (d) the volume of segment k .

Thomann expresses this in the form of a first order difference equation. The equation for segment k is given by

$$V_k \frac{dc_k}{dt} = Q_{k-1,k} \frac{(c_{k-1} + c_k)}{2} - Q_{k,k+1} \frac{(c_k + c_{k+1})}{2} \\ E_{k-1,k} (c_{k-1} - c_k) + E_{k,k+1} (c_{k+1} - c_k) + V_k f_k(t). \quad (16)$$

where c_k is the concentration of the component of interest in the k th segment;

V_k is the volume of segment k ;

$Q_{k-1,k}$ denotes the net flow from segment $k-1$ to k ;

$E_{k-1,k}$ is the dispersion coefficient between $k-1$ and k ;

$f_k(t)$ net sum of all sources and sinks of the component in the k th segment.

A set of equations like (16) is obtained, one for each segment for both dissolved oxygen and BOD. These equations have been solved both with and without the assumption of $dc/dt = 0$. If $dc/dt = 0$, the set of equations can be expressed in matrix notation as

$$A\bar{c} = \bar{F}$$

where: A is a matrix of equation coefficients.
 $\bar{c}$ is a vector of average segment concentrations.
 $\bar{F}$ is a vector of BOD or OD sources and sinks.

These equations can be solved simultaneously by inverting A and multiplying through by the matrix A^{-1} , yielding

$$c = A^{-1}\bar{F}$$

Since the equation for each segment has terms involving concentrations in just three segments (the segment of interest and the segments on either side), matrix A reduces to an easily invertible tridiagonal matrix. Thus the vector $\bar{c}$ can be easily found but its usefulness is limited by assumptions on which the above development rests.

Explicitly or implicitly the following assumptions and therefore limitations have been imposed on the above model

- I. It has been assumed that the concentration gradients can be accurately approximated by straight lines.
- II. Steady state conditions have been assumed.
- III Concentration variations within the tidal cycle cannot be simulated.
- IV. Concentrations, estuary characteristics, process parameters, etc., are constant within a segment.

Pence, Jeglic and Thomann (61b) have numerically solved equation (16) above for $dc/dt \neq 0$, thus removing limitation II. However, limitations I, III, and IV still hold.

ORLOB'S MODEL

G. T. Orlob et. al. [61a,61b] developed a two dimensional model which permits a more accurate approximation of the advection effects in a shallow estuary. Two major computer programs must be used in the application of this model: a hydraulics program and a water quality program. The output from the hydraulics program is used as one of the inputs to the water quality program.

The hydraulics model approximates a one or two dimensional bay or estuary with an analogous network of idealized channels. The program is geared to specific tide and river flow conditions and must be reworked for each change in these conditions. The water quality model is essentially a time dependent Thomann model. The overall effect of this model is that the hydraulics of the estuary can be more accurately approximated.

HARLEMAN'S MODEL

Harleman, Lee, and Hall (31A) numerically solved a coupled set of two, one-dimensional diffusion equations of the following form.

$$\frac{\partial c}{\partial t} = \frac{1}{A} \frac{\partial}{\partial x} (AE \frac{\partial c}{\partial x}) - U \frac{\partial c}{\partial x} + R_a - R_r \quad (16a)$$

where: c = average cross sectional concentration as a function of time and position.

U = average cross sectional fluid velocity.

A = cross sectional area.

E = diffusion coefficient.

R_a = rate of input of component c due to all sources.

R_r = rate of disappearance of c due to all sinks.

One equation described DO and another BOD concentrations.

Comparison with equation (16) indicates that (16a) is a more general form of the diffusion equation and for this reason would be expected to describe more accurately the diffusion and dispersion effects of an estuary. This model does not handle the hydraulic effects as accurately as does the Orlob model.

PREVIOUS STOCHASTIC MODELS

THE MODEL OF THAYER AND KRUTCHKOFF

Thayer and Krutchkoff developed a stochastic model for BOD and DO streams, [71,72]. Their work was based on Dobbin's model, with the mechanisms effecting BOD and DO concentrations modified so as to be random in nature.

Thayer and Krutchkoff made one additional assumption. The pollution and dissolved oxygen were discretized. The term Δ was introduced to represent the optimum unit size. All transitions in BOD and DO were asserted to be in units of size Δ . Δ is a measurable parameter of the individual stream. Methods of estimating Δ will be given later.

A change of size Δ in the concentration constitutes a change of one "state". The pollution state m corresponds to a concentration of L_m and the relationship between the two is

$$\text{State } m = L_m / \Delta. \quad (17)$$

Similarly, DO state n corresponds to concentration $n\Delta = D_n$.

Dobbins' assumption concerning the processes in the stream were replaced by their stochastic analogues. In a small time increment h , the pollution or DO can be increased or decreased by Δ or a multiple of Δ by each of the mechanisms considered by Dobbins. The mechanisms are assumed to act independently. The order of magnitude of h will be such that h^2 will be negligible in comparison to h . The probability of change in state is assumed proportional to h , thus a change of more than one state by a single factor in time h has probability $o(h)$. Terms of probability $o(h)$ can be neglected when terms of order h are present. The probability of one change in state for each of the factors is as follows:

1. The expected amount of increase in pollution due to L_m in the time interval h is $L_m h$. Letting $p = \text{Pr} [\text{Pollution increases by amount } \Delta \text{ due to } L_m \text{ in time } h],$

one obtains the expected increase due to L_a in time h to be $\Delta p + o(h) + O \cdot (1-p-o(h))$.

Therefore, $p = L_a h / \Delta + o(h)$. By similar arguments:

2. $\text{Pr}[\text{Pollution decreased by an amount } \Delta \text{ due to } K_3 \text{ in time } h] = K_3 L_a h / \Delta + o(h)$.

3. $\text{Pr}[\text{Pollution decreases and OD increases by an amount } \Delta \text{ due to } K_1 \text{ in time } h]$

$$K_1 L_a h / \Delta + o(h).$$

4. $\text{Pr}[\text{OD increases by an amount } \Delta \text{ due to } D_0 \text{ in time } h] = D_0 h / \Delta + o(h)$.

5. $\text{Pr}[\text{OD decreases by an amount } \Delta \text{ due to } K_2 \text{ in time } h] = K_2 D_n h / \Delta + o(h)$.

The joint probability of finding the system with pollution in state m and the oxygen deficit in state n at time t is denoted by $p_{m,n}(t)$. Combining the factors 1 through 5 one obtains the difference equation

$$\begin{aligned} p_{m,n}(t+h) = & p_{m,n}(t) \left[1 - \frac{L_a h}{\Delta} - \frac{K_3 L_a h}{\Delta} \right. \\ & - \frac{K_1 L_a h}{\Delta} - \frac{D_0 h}{\Delta} - \left. \frac{K_2 D_n h}{\Delta} \right] + p_{m-1,n}(t) \frac{L_a h}{\Delta} + p_{m+1,n}(t) K_3 (m+1) h \\ & + p_{m+1,n-1}(t) K_1 (m+1) h + p_{m,n-1}(t) \frac{D_0 h}{\Delta} + p_{m,n+1}(t) K_2 (n+1) h \\ & + o(h). \end{aligned} \quad (18)$$

Let $P(s,r,t)$ be the probability generating function of $p_{m,n}(t)$, i.e.,

$$P(s,r,t) = \sum_{m=0}^{\infty} \sum_{n=0}^{\infty} p_{m,n}(t) s^m r^n \quad (19)$$

Taking limits as h approaches 0 the following differential equation in $P(s,r,t)$ is derived:

$$\frac{\partial \ln P}{\partial t} + K_3 (r-1) \frac{\partial \ln P}{\partial r} - K_3 (1-s)$$

$$+ K_1 (r-s) \frac{\partial \ln P}{\partial s} = L_a / \Delta (1-s) + D_0 / \Delta (1-r). \quad (20)$$

Thayer and Krutchkoff obtained analytic solutions for $P(x, r, t)$ for several sets of initial conditions. The solutions corresponding to the initial condition that the BOD concentration is L_0 and the OD is D_0 at $t = 0$ will be useful in our applications. For these initial conditions the solution to equation (20) is

$$\begin{aligned} P(s, r, t) = & \exp \left[\frac{-L_a K_1}{\Delta (K_1 + K_3) (K_2 - (K_1 + K_3))} \right. \\ & \cdot (1 - e^{-(K_1 + K_3)t}) (1-r) + \frac{L_a K_1}{\Delta K_2 (K_2 - (K_1 + K_3))} (1 - e^{-K_2 t}) (1-r) \\ & - \frac{L_a}{\Delta (K_1 + K_3)} (1 - e^{-(K_1 + K_3)t}) (1-s) + \frac{D_0}{\Delta K_2} (1 - e^{-K_2 t}) (1-r) \left. \right] \\ & \cdot [1 - (1-r) e^{-K_2 t}] D_0 / \Delta \cdot [1 - \frac{K_1}{K_2 - (K_1 + K_3)} (e^{-(K_1 + K_3)t} - e^{-K_2 t}) \cdot \\ & (1-r) - e^{-(K_1 + K_3)t} (1-s)] L_0 / \Delta. \quad (21) \end{aligned}$$

Equation (21) can be put in some what more manageable form if several reoccurring groups of symbols are redefined.

$$\alpha_1(t) = e^{-(K_1 + K_3)t}$$

$$\beta_1(t) = 1 - \alpha_1$$

$$\alpha_2(t) = \frac{K_1}{K_2 - (K_1 + K_3)} (e^{-(K_1 + K_3)t} - e^{-K_2 t})$$

$$\beta_2(t) = 1 - \alpha_2$$

$$\alpha_3(t) = e^{-K_2 t}$$

$$\beta_3(t) = 1 - \alpha_3$$

$$\gamma = \frac{L_a K_1}{(K_2 - (K_1 + K_3))}.$$

Rewriting equation (21) gives

$$P(s, r, t) = \exp \left\{ (1-r) \left[\frac{\gamma \beta_1}{\Delta (K_1 + K_3)} + \frac{\gamma \beta_2}{K_2} + \frac{D_0 \beta_3}{K_2} \right] - \frac{L_a \beta_1}{\Delta (K_1 + K_3)} (1-s) \right\}.$$

$$[1-(1-r)\alpha_3]^{D_0/\Delta} [1-(1-r)\alpha_2-(1-s)\alpha_1]^{L_0/\Delta}. \quad (22)$$

Thayer and Krutchkoff obtained the marginal generating functions for BOD and OD from (21) by setting $r = 1$ and $s = 1$, respectively. They were able to pick out the coefficient of s^n and r^n . The coefficients are functions of t . These coefficients give the complete pollution and oxygen deficit distributions. The means of the distributions were identical to Dobbins' equations; (14) and (15). The variances were linear functions of Δ given by:

$$\text{VAR}(L) = \Delta \left[\frac{L_a}{K_1 + K_3} + L_a \alpha_1(t) \right] \beta_1(t) \quad (23)$$

$$\begin{aligned} \text{VAR}(D) = \Delta & \left[-\frac{\gamma}{K_2} \beta_3(t) + \frac{\gamma}{K_1 + K_3} \beta_1(t) \right. \\ & + \frac{D_a}{K_2} \beta_3(t) + D_0 \beta_3(t) \alpha_3(t) \\ & + \gamma(\alpha_1(t) - \alpha_3(t)) \left(1 - \frac{\gamma}{L_a} (\alpha_1(t) \right. \\ & \left. \left. - \alpha_3(t)) \right) \right]. \quad (24) \end{aligned}$$

THE MODEL OF MOUSHEGIAN AND KRUTCHKOFF

Moushegain and Krutchkoff [55] extended the Thayer and Krutchkoff model to permit segmentation of the stream. In essence they determined that one could treat the probability output of one segment as the probability input to the next segment. This was only a crude approximation which neglected the dependence in the probability distributions of BOD and DO. A study of the effect of this approximation was made. The approximation was found to be remarkably good. It was the success of this procedure for streams (not estuaries) which took the present project into a blind ally.

THE MODEL OF CUSTER AND KRUTCHKOFF

The model of Custer and Krutchkoff [13,14] is an extension of the model of Thayer and Krutchkoff to estuaries. A random walk mechanism is postulated as opposed to the birth-death process used by Thayer and Krutchkoff. The random walk mechanism permits the representation of the true diffusion effect; not the effect confounded with tidal motion. For this reason the term diffusion is used in lieu of dispersion.

The diffusion model considers all factors considered by Dobbins in his deterministic work, and consequently by Thayer and Krutchkoff, except

a) L_a the uniform increase of BOD by land runoff,

b) D_b the decrease in DO due to the benthic demand

These factors are handled separately, and their effect added by the principle of superposition.

As in the work of Thayer and Krutchkoff, the pollution and dissolved oxygen are discretized into units of size Δ . A Δ unit is such that it cannot be further decomposed into smaller units. Pollution must be degraded by the bacteria and other mechanisms in units of size Δ or multiples of Δ .

First, the motion of a single BOD unit is considered. This motion is treated as a random walk with decay on the real axis. In each time interval δt , the unit has probability $p(t)$ of taking a positive step of length δx , probability $q(t)$ of taking a negative step of length δx , and probability r of being absorbed. A difference equation is obtained which gives the joint probability of the unit being at any location x after any time t , given that the unit was at the origin at time t_0 (if x is not a multiple of δx this probability is zero). $p(t)$, $q(t)$, r , δx , and δt can be determined from the physical parameters of the estuaries.

The diffusing process of a unit of oxygen deficit, (OD) is handled in a similar manner, with the initial conditions slightly modified. Unlike the BOD units which originate at a uniform rate, a unit of OD is formed simultaneously with the absorption of a unit of BOD.

The parameter δt used in the random walk procedure is the length of time needed for one unit of size Δ to enter the estuary. Thus, δt is a function of the rate at which pollution enters from the source, and the cross-sectional area of the estuary. In order to obtain the effect of a continuous source, units of size Δ are released at each time interval δt . The units act independently and their behavior can be studied individually by the random walk mechanism. Thus, the probability of a given concentration at location x after time t is the convolution of the probabilities associated with the individual units

The resulting model is a transient state model; the time parameter being defined as the time lapse since the source of pollution originated.

Due to the fact that the velocity of the estuary is a function of time, the distribution will be continually changing in time and no steady state is possible. However, after a sufficient time lapse the distribution for a given point in the tidal cycle remains constant from cycle to cycle. This will be defined as a pseudo-steady state condition. The pseudo-steady can be described by taking the time lapse to be sufficiently large. In most cases 15 to 25 days will be 99% of pseudo-steady state.

The motion of a single particle placed in a medium where it is exposed to a great number of random forces is described by what is commonly called "diffusion." The diffusion process considered in the analysis was first developed by Einstein in relation to the Brownian motion problem. Literature concerning the Brownian motion problem is extensive. Heuristic development of the limiting process leading to the renowned Fokker-Planck Equation are given by Feller [23], Rosenblatt [65], Bharucha-Reid [9] and others [6,42,62]. More advanced treatments are rendered by Feller [24,25,26], Doob [20] and Kac [41]. Geneticists have been particularly active in investigating the stochastic nature of the diffusion phenomenon [23,46]. Although this is not the only mathematical description of the diffusion process it is the most widely used and verified. The general treatment concerns the motion of a non-conservative process.

The general assumption for this process is that it is certain that the particle will move in any interval of time δt ; however, if δt is small the movement will be small. The forces acting on the particle can be summarized by two components: The symmetric random forces described as diffusion and the non-symmetric drift, or in this case, velocity. In the estuary velocity is a function of time. In addition, when working with non-conservative substances, such as BOD or DO, the possibility of absorption must be included.

The motion of a BOD unit is characterized as follows: in each time lapse of length δt the unit moves forward on the positive axis a distance δx with probability $p(t)$, or backwards the distance δx with probability $q(t)$. This is the only motion possible. However, at each time lapse of length δt the unit may be absorbed and lost to the system. The probability of absorption is constant at r . Of course

$$p(t) + q(t) + r = 1 \text{ for all } t. \quad (25)$$

Let $u(m,n)$ be the probability that after n steps the unit of BOD is at location $m\delta x$. The total time lapse t will be $n\delta t$.

The unit may be at location $m\delta x$ after n steps in either of two ways:

1. the unit is at $(m-1)\delta x$ at $(n-1)\delta t$ and takes a positive step, or
2. the unit is at $(m+1)\delta x$ at $(n-1)\delta t$ and takes a negative step.

Thus

$$u(m,n+1) = u(m-1,n)p(n\delta t) + u(m+1,n)q(n\delta t) \quad (26)$$

for

$$m, n \in I, \quad -\infty < m < \infty \text{ and } 0 \leq n < \infty.$$

Remaining consistent with the physical interpretation of the Brownian motion process, the following values for the terms in equation (26) are adopted:

$$\frac{(\delta x)^2}{\delta t} = 2E, \quad (27)$$

$$p(t) = (1-K_d \delta t)/2 + \frac{U(t)}{2} \frac{\delta t}{\delta x}, \quad (28)$$

$$q(t) = (1-K_d \delta t)/2 - \frac{U(t)}{2} \frac{\delta t}{\delta x}, \quad (29)$$

$$r = K_d \delta t \quad (30)$$

where

E is the diffusion coefficient,

K_1 is the coefficient of deoxygenation,

K_3 is the coefficient corresponding to all non-oxygen consuming processes,

K_d is $K_1 + K_3$,

and

$U(t)$ is the velocity function.

δt is defined as the length of time required for one unit of size Δ to enter the estuary, and may be calculated from physical parameters. With the value of δt and the relations given above, all components in the difference equation may be evaluated.

In order to solve equation (26) a set of initial conditions is required. Given that the unit entered the system at time t_0 (t_0 must be divisible by δt), the initial conditions are

$$u(0, n_0) = 1.$$

$$u(m, n_0) = 0 \text{ for } m \neq 0,$$

$$u(m, n) = 0 \text{ for } n < n_0,$$

where

$$n_0 = t_0 / \delta t. \quad (31)$$

Under these initial conditions $u(m, n)$ will be written $u(m, n | n_0)$.

To derive the difference equation for oxygen deficit, it must be recalled that the absorption of a unit of BOD generates a unit of OD of equal size. The OD is then absorbed from the system by reaeration in the same manner that BOD is absorbed by the bacteria.

One can think of a unit being released at t_0 as BOD. The BOD travels in accordance with the random walk mechanism until it is absorbed; however, the absorption is only a metamorphosis which changes the identity of the BOD and OD. The renamed unit then resumed the random walk at the point where it was absorbed, now governed by the probabilities associated with OD.

Let $v(m,n)$ be the probability that a unit of OD is at location $m\delta x$ after time $n\delta t$, where δx and δt are as before. The probability of a forward step will be represented by $p(t)$, a negative step by $q(t)$, and absorption by r . An OD unit can be at $m\delta x$ after time $n\delta t$ in any of three ways;

1. the unit is at $(m-1)\delta x$ at $(n-1)\delta t$ and takes a step forward,
2. the unit is at $(m+1)\delta x$ at $(n-1)\delta t$ and takes a step backwards,
3. the unit is BOD located at $m\delta x$ at $(n-1)\delta t$, and is transformed in OD.

Thus,

$$v(m,n+1) = v(m-1,n)p(n\delta t) + v(m+1,n)q(n\delta t) + u(m,n)K_1\delta t \quad (32)$$

for

$$m,n \in I, \quad -\infty < m < \infty, \quad \text{and} \quad 0 \leq n < \infty.$$

The transition probabilities are defined as follows:

$$p(t) = (1-K_2\delta t)/2 + \frac{U(t)}{2} \frac{\delta t}{\delta x}, \quad (33)$$

$$q(t) = (1-K_2\delta t)/2 - \frac{U(t)}{2} \frac{\delta t}{\delta x}, \quad (34)$$

$$\tilde{r} = K_2\delta t, \quad (35)$$

where K_2 is the coefficient of reaeration, and the other parameters were defined following equation (30).

The initial condition is

$$v(m,n) = 0 \text{ for all } m \text{ if } n < n_0. \quad (36)$$

$v(m,n|n_0)$ will represent $v(m,n)$ under condition (36).

In the above work practical difficulties arose due to the small size of δt . Fortunately this could be used to advantage. As δt approaches zero, limiting results which approximate $u(m,n|n_0)$ and $v(m,n|n_0)$ could be obtained.

As δt approaches zero the probabilities $u(m,n|n_0)$ and $v(m,n|n_0)$ approach continuous densities. These densities will be denoted by $f(x,t|t_0)$ and $g(x,t|t_0)$, respectively. Recalling that the location on the real axis corresponding to m is $m\delta x$, and the time corresponding to the n th step is $n\delta t$, equations (26) and (32) can be rewritten as follows:

$$f(x,t+\delta t|t_0) = f(x-\delta x,t|t_0)p(t) + f(x+\delta x,t|t_0)q(t), \quad (37)$$

$$g(x,t+\delta t|t_0) = g(x-\delta x,t|t_0)p(t) + g(x+\delta x,t|t_0)q(t) + f(x,t|t_0)K_1\delta t. \quad (38)$$

Expanding the terms in (37) in a truncated Taylor series about (x,t) it can be shown that (37) becomes

$$\frac{\partial f(x,t|t_0)}{\partial t} = E \frac{\partial^2 f}{\partial x^2} - U(t) \frac{\partial f}{\partial x} - K_1 f(x,t|t_0) \quad (39)$$

Similarly, equation (38) becomes

$$\frac{\partial g(x,t|t_0)}{\partial t} = E \frac{\partial^2 g}{\partial x^2} - U(t) \frac{\partial g}{\partial x} - K_2 g(x,t|t_0) + K_1 f(x,t|t_0). \quad (40)$$

Notice that none of the parameters are functions of position and only velocity is a function of tidal phase.

These equations are solved analytically for f and g holding all parameters constant with position with the following results.

$$f(x, t | t_0) = \frac{1}{2\sqrt{\pi(t-t_0)}E} \exp\left\{-\frac{(x-v(t))^2}{4E(t-t_0)} - K_d(t-t_0)\right\} \quad (41)$$

and

$$g(x, t | t_0) = \frac{K_1}{2(K_2 - K_d)\sqrt{\pi E(t-t_0)}} \exp\left\{-\frac{(x-v(t))^2}{4E(t-t_0)}\right\} \cdot [\exp\{-K_1(t-t_0)\} - \exp\{-K_2(t-t_0)\}] \quad (42)$$

where:

$$v(t) = \int_{t_0}^t U(\tau) d\tau.$$

The resulting $f(x, t | t_0)$ and $g(x, t | t_0)$ are the conditional probability density functions that a single BOD or OD particle will be at position x at time t given that it was released at time t_0 . To find the probabilities for the total concentrations due to all BOD or OD particles present it would be necessary to convolute over all the individual BOD or OD particles present.

Custer does this by temporarily reverting to the discrete process. The event of a particular BOD or OD being at x at time t was considered to be a bernoulli probability generating functions were derived.

$$P(m, n, s) = \prod_{i=0}^n [(1-u(m, n|i) + u(m, n|i)s)] \quad (43)$$

for BOD probabilities

and

$$\tilde{P}(m, n, s) = \prod_{i=0}^n [(1-v(m, n|i) + v(m, n|i)s)] \quad (44)$$

Where $u(m, n|i)$ and $v(m, n|i)$ were defined previously. Utilizing the properties of probability generating functions the following means and variances were defined.

$$\text{MEAN(BOD state)} = \sum_{j=0}^n u(m, n|j) \quad (45)$$

$$\text{VAR(BOD state)} = \sum_{j=0}^n u(m, n|j) - \left(\sum_{j=0}^n u(m, n|j)\right)^2 \quad (46)$$

$$\text{MEAN(OD state)} = \sum_{j=0}^n v(m,n|j) \quad (47)$$

$$\text{VAR(OD state)} = \sum_{j=0}^n v(m,n|j) - \sum_{j=0}^n (v(m,n|j))^2 \quad (48)$$

By letting the time interval between successive BOD particles approach zero, the input becomes a continuous source and the probability mass functions become probability density functions. That is $u(m,n|j)$ and $v(m,n|j)$ approach $f(x,t|t_0)$ and $g(x,t|t_0)$. Then the probability of an individual successes can be restated as

$$u(m,n|i) \approx f(x,t|t_1) \delta x \quad (49)$$

for BOD and

$$v(m,n|i) \approx g(x,t|t_1) \delta x \quad (50)$$

for OD.

Still retaining the discrete notation it can be shown that this sum of bernoulli trials approaches a poisson distribution as δt (and hence δx) approaches zero. The state mean and variance are the same.

The significance of this result is that once the mean concentration of BOD and OD is determined, the poisson variance is known and the entire distribution can be found.

PURPOSE OF THIS PROJECT

The purpose of this project is to expand and further verify the model of Custer and Krutchkoff. Specifically the project can be divided into four tasks.

INCLUDE A VARIABLE SOURCE

Both the Thayer and Krutchkoff and the Custer

and Krutchkoff models consider constant sources. Examples of variable or random inputs have been given [71,72] for the Thayer and Krutchkoff model but these situations were not considered by Custer and Krutchkoff. The first task for this project is to adapt the model to accept variable or random input loadings.

SEGMENTED ESTUARY MODEL

In the Custer and Krutchkoff report [13] it was noted that the problem of segmenting an estuary is not a simple problem in a stochastic model. The second task in this project is to obtain a segmented estuary model. This can be done either by adjusting the Custer and Krutchkoff model or by obtaining a new model.

VERIFY THE MODEL

The third task is to use data supplied by WQO obtained from the Potomac Estuary, the Ohio River and the Delaware Estuary to verify the models obtained in tasks one and two. This means that the model will have to predict not only the mean concentration of both BOD and DO for both a stream and an estuary but it must also predict the distributions about these means.

OBTAIN A METHOD FOR PREDICTING Δ

The stochastic parameter Δ enters as a scale factor in the variation about the mean concentration of both BOD and DO. Bosley, Cibulka and Krutchkoff [10] demonstrated that this stochastic parameter was a function of the parameters and properties of the stream. The fourth task in this project is to obtain a method for estimating the appropriate value of Δ from actual data and obtain a regression equation which could then be used in predicting future values of Δ .

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

VARIABLE OR RANDOM INPUTS

SIMULATED CASE STUDIES

Before attempting to solve this problem analytically a stochastic simulation was made (see [8]). In this simulation study the random walk situation was simulated. n pollution particles entered the estuary at a point and performed a random walk up and down the estuary with probabilities given by equations (28) and (29) and with probability of being absorbed given by equation (30). When a particle is absorbed it was turned into an Oxygen Deficit (OD) particle and performed a random walk up and down the estuary with probabilities given by equation (33) and (34). The OD particle could also be eliminated by reaeration with probability given by equation (35).

The computer program was so written that the motions simulated estuaries with the usual parameters. Variable and random inputs of several types were used. The results are presented in 24 graphs given in [8]. Figures 1 and 2 are the first two graphs from that report and are typical results. The four curves shown are the mean concentrations obtained by simulation for four different inputs. The curve marked "Mean 5" is the constant input result while the other three represent a binomial distribution, a uniform (random) distribution, and a two point distribution (ten and zero) all with mean value equal to five. As can be seen from the figures there is no significant difference in the mean values for any of these inputs. All 24 graphs indicated similar results. Conclusion: Short term random variations of the input has little if any effect on the mean concentration down estuary.

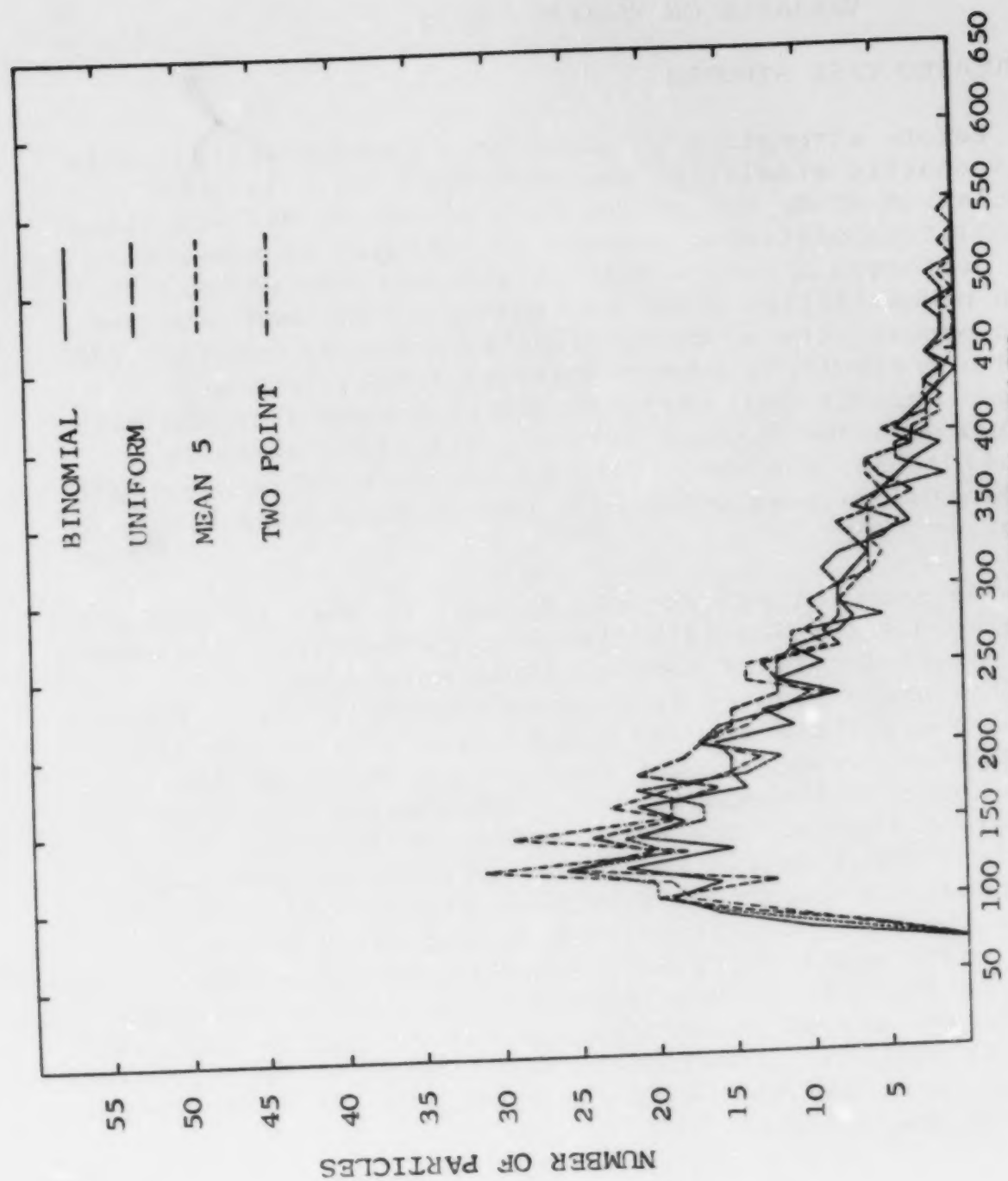


FIGURE 1 BIOCHEMICAL OXYGEN DEMAND -SITUATION 1
SECTION OF ESTUARIAL REACH

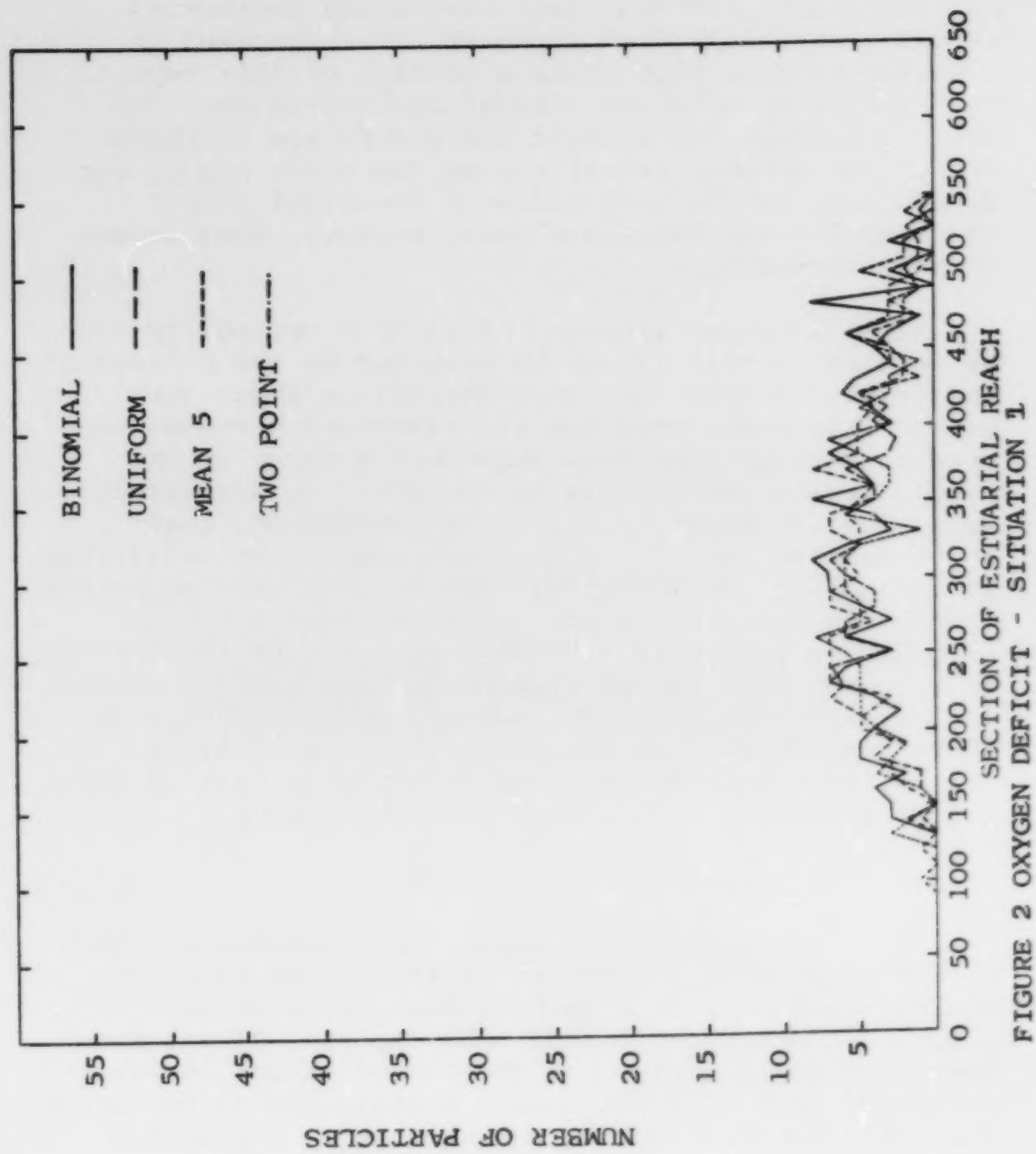


FIGURE 2 OXYGEN DEFICIT - SITUATION 1

ANALYTICAL RESULTS

The results of the simulation study encouraged a full scale analytical approach. The approach is reported in detail in another section of this report. The results were as the simulations indicated. The mean concentrations of both BOD and DO are independent of the random variability of the input source and depend only on the mean value of the input source. The distribution about the mean, however, does depend on this variability.

As will become apparent later, this variability can be ignored in that it can be absorbed by the Poisson Approximation used for the distribution about the mean. This means that for all practical purposes one need only obtain the time dependent average of the input loading and not its distribution to adequately employ The Stochastic Model. For example, the load might have an overall sinusoidal shape with short-term random variations about this shape. One can completely ignore the variation about the sinusoidal function if only the mean effect is desired. If the fluctuation is not too large it can also be ignored when obtaining the distribution about the mean, provided the Poisson Approximation is used to obtain this distribution. This Poisson Approximation is an integral part of this report and will be discussed in detail later.

SEGMENTING AN ESTUARY

It is not possible to treat the probability output of one segment of an estuary as the random input of the next segment. The mathematical proof of this is given in another section of this report. It was found that in order to solve for the output of one segment, equations involving the entire estuary had to be solved. For this reason it was necessary to obtain a method for solving all the equations necessary for a segmented estuary at the same time. Although the task seemed impossible at first, it became apparent that the problem could be solved. Not only could the estuary be segmented

but the parameters could be continuous functions of both time and space. The derivations are given in a later section and will only be summarized here.

The problem is divided into two parts. Finding the mean concentration and finding the distribution about the mean using the Poisson Approximation. In order to solve for the mean concentration the following equations are solved numerically on a computer. The equations are:

$$\frac{\partial f(x,t)}{\partial t} = E_f(x,t) \frac{\partial^2 f}{\partial x^2} - U(x,t) \frac{\partial f}{\partial x} - K_d(x,t)f + L_R(x,t) + FF(x,t) \quad (51)$$

and

$$\frac{\partial g(x,t)}{\partial t} = E_g(x,t) \frac{\partial^2 g}{\partial x^2} - U(x,t) \frac{\partial g}{\partial x} - K_2(x,t)g + K_1(x,t)f + D_0(x,t) \quad (52)$$

where:

- $f(x,t)$ is the BOD concentration
- $g(x,t)$ is the OD concentration
- $K_d(x,t)$ is the coefficient for the decrease of BOD by all processes, including biological utilization and all non-oxygen consuming processes, i.e. $K_d(x,t) = K_1(x,t) + K_3(x,t)$
- $K_1(x,t)$ is the coefficient for biological utilization
- $K_3(x,t)$ is the coefficient of all non-oxygen consuming processes
- $U(x,t)$ is the velocity of the water in the estuary
- $K_d(x,t)f$ is the rate of decrease in BOD due to oxygen and non-oxygen consuming processes
- $L_R(x,t)$ is the rate of increase in BOD due to land runoff
- $FF(x,t)$ is the rate of increase in BOD due to STP outputs
- $K_2(x,t)g$ is the rate of decrease in OD due to reaeration

$K_1(x,t)f$ is the rate of increase in OD due to oxidation of BOD

$D_b(x,t)$ is the rate of increase in OD due to benthic demand. Normally photosynthesis will be included in this term.

The program used to solve these equations is given in the appendix.

The analytical results indicate that the distribution of concentration state (not concentration) has a poisson distribution. From this it can be shown that the distribution of the concentration itself has a poisson shaped distribution, centered at the concentration mean, but with variance equal to Δ times the mean concentration. Therefore, since the solution to the above equations provide the mean, and Δ is available (see the section labeled PREDICTING Δ), we can obtain the appropriate variance. Knowing the variance and the center of the poisson-like distribution the probability distribution can easily be obtained. If the mean concentration is near zero, then the discrete poisson distribution must be smoothed out to provide a more realistic distribution. It is this distribution about the mean which indicates the proportion of the time that the concentration will be above or below any level. Details of these results are provided later.

VERIFICATION OF THE MODEL

VERIFICATION ON AN IMPOUNDED STREAM

Between 1957 and 1963 a three phase program was conducted on the Markland pool near Cincinnati, Ohio. The objective to this work was to evaluate the effect of the high rise Markland dam on the waste assimilative capacity of the Ohio River. Data taken in the third stage of this study (post-impoundment conditions) was used here for model verification. Individual BOD and OD samples were taken every 3 hours at 8 stations. The results of that analysis are given in another section of this report. The result for the mean

concentration is summarized in Figure 3. Note how well the theoretically predicted values for both BOD and OD compare with the average values actually observed

The Poisson Approximation method was then used to obtain the distributions about these means. A very stringent test was then given the obtained distributions. Two sided confidence intervals were obtained from the distribution for confidences 0.10, 0.15, 0.20, 0.30, 0.40, and 0.50. Two sided intervals were used to detect any departure from the predicted degree of skewness. The observed results for the last six stations are presented in Table 1. The observed results are remarkably close to the predicted values at every station. Thus the general stochastic model obtained in this project can be said to work well for streams, even impounded streams.

VERIFICATION ON A SEGMENTED ESTUARY

In the summer of 1967 an intensive DO and water temperature survey was conducted for the Potomac estuary. Sampling was done at four stations which cover the upper 30 miles of the estuary. This stretch provided a good test for the ability of the model to treat a segmented estuary. The details of the analysis are reported elsewhere in this report. Since there was no BOD study made in that survey the only comparison which could be made was that of Dissolved Oxygen. Unfortunately no time dependent study was made of the photosynthesis. In order to minimize this effect only data taken between 5 am and 9 am could be used. This did not prove to be much of a limitation since the data was taken every 30 minutes for at least two weeks at each station. The mean concentrations fit well at the first three stations but the lack of nitrogen and carbon recycle information made the analysis invalid for station number 4. The model can be extended to include the nitrogen cycle including algae but this has not yet been done. Figures 4, 5, and 6 are comparisons of the predicted mean OD and the observed average OD at each

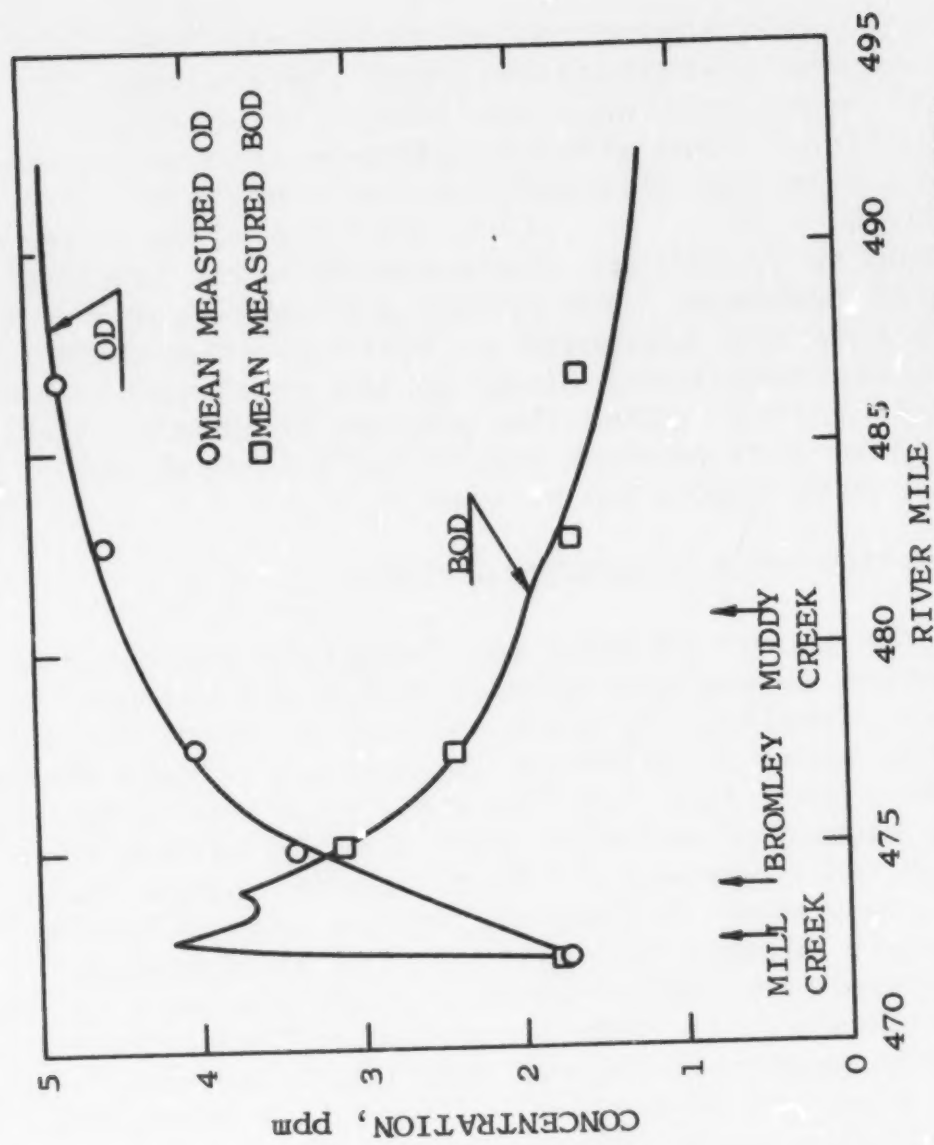


FIGURE 3 A COMPARISON OF PREDICTED AND OBSERVED
BOD AND OD MEAN CONCENTRATIONS IN THE
MARKLAND POOL OF THE OHIO RIVER

Table 1: Observed vs. predicted fraction of values outside specified concentration confidence intervals for the Ohio River.

Fraction Predicted Outside of C. I.	Fraction Observed Outside of C. I. by Station					
	3	4	5	6	7	8
<u>BOD</u>						
0.10	0.148	0.045	0.082	0.141	0.126	0.133
0.15	0.185	0.141	0.156	0.170	0.141	0.200
0.20	0.236	0.274	0.163	0.230	0.245	0.252
0.30	0.333	0.318	0.245	0.304	0.311	0.296
0.40	0.429	0.485	0.362	0.429	0.415	0.429
0.50	0.563	0.510	0.532	0.541	0.445	0.490
<u>OD</u>						
0.10	0.140	0.096	0.104	0.111	0.111	0.140
0.15	0.163	0.126	0.148	0.126	0.119	0.156
0.20	0.208	0.222	0.170	0.170	0.140	0.192
0.30	0.341	0.318	0.296	0.267	0.215	0.267
0.40	0.378	0.400	0.415	0.407	0.349	0.341
0.50	0.452	0.482	0.482	0.490	0.467	0.437

Station 1 and 2 were not used since their values had been used as upstream boundary conditions. There were 135 observations/station.

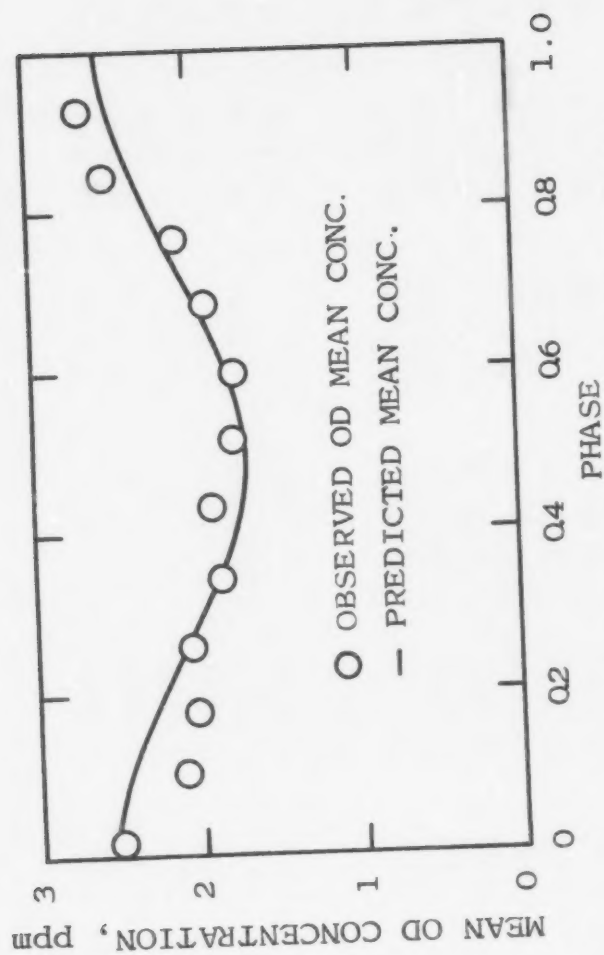


FIGURE 4 COMPARISON OF PREDICTED AND OBSERVED OD CONCENTRATION AS FUNCTIONS OF TIDAL CYCLE FOR STATION 1, POTOMAC ESTUARY

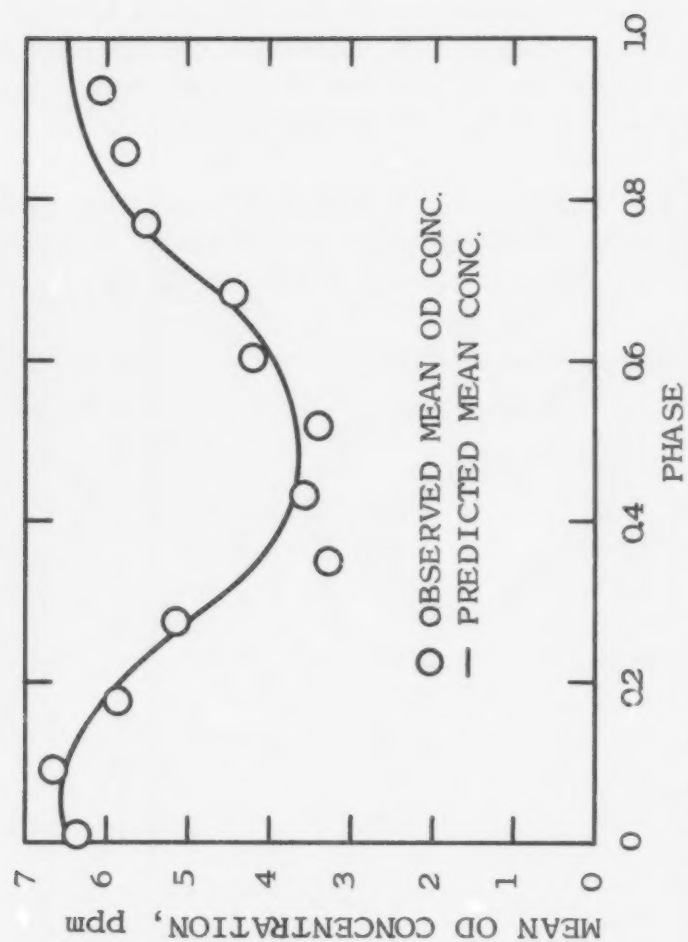


FIGURE 5 COMPARISON OF PREDICTED AND
OBSERVED OD CONCENTRATION AS
FUNCTIONS OF TIDAL CYCLE FOR
STATION 2, POTOMAC ESTUARY

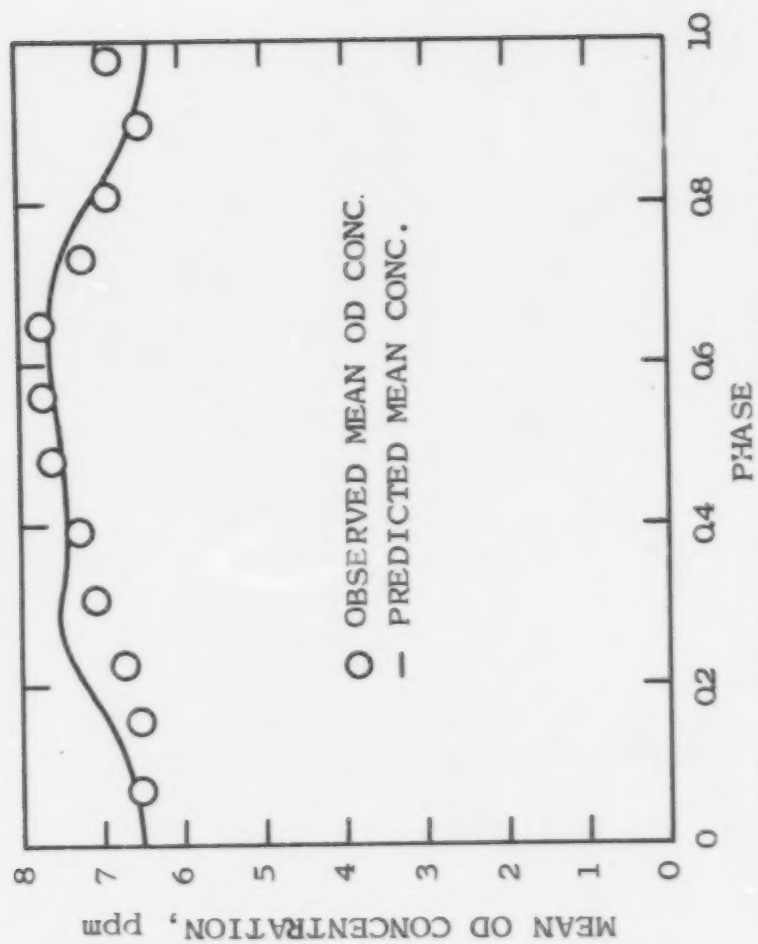


FIGURE 6 COMPARISON OF PREDICTED AND OBSERVED OD CONCENTRATION AS FUNCTIONS OF TIDAL CYCLE FOR STATION 3, POTOMAC ESTUARY

of the first three stations. The predictions can be seen to be quite close to the observed values at all three stations. The results of the confidence interval comparisons at the first three stations is given in Table 2. Once again the observed frequencies are remarkably close to the predicted frequencies. Station 3 has concentrations of DO near zero. This means that the poisson distribution was extremely skewed and also required smoothing. In spite of this the results are reasonably good.

Table 2: Observed vs. predicted fraction of values outside specified concentration confidence interval for the Potomac Estuary

<u>Fraction Predicted Outside of C. I.</u>	<u>Fraction Observed Outside of C. I.</u>		
	<u>Station 1</u>	<u>Station 2</u>	<u>Station 3</u>
0.05	0.100	0.055	0.087
0.10	0.10	0.087	0.111
0.15	0.141	0.127	0.111
0.20	0.193	0.167	0.135
0.25	0.242	0.199	0.151
0.30	0.285	0.246	0.175
0.35	0.335	0.310	0.184
0.40	0.380	0.365	0.230
0.50	0.470	0.500	0.477

Station 1 - 270 observations

Station 2 - 126 observations

Station 3 - 126 observations

PREDICTING Δ

Although there has been a good deal of discussion concerning Δ (see [17,50,10]) its properties and, more importantly, its true meaning were still unsettled. The papers [50] and [10] demonstrated that Δ is indeed a physical parameter but the interpretation given to it in the Thayer and Krutchkoff and the Custer and Krutchkoff

models was still unappealing. In these models pollution or DO could change in concentration only in units of size Δ . This is unappealing for several reasons. Firstly, the fact that it pertains to concentration units rather than absolute quantities. This means that it could possibly represent tons of BOD. Secondly, it does not allow for smaller changes in conditions where the concentrations are very low. Thirdly, it required the same Δ for both BOD and DO. Before finding a method to predict Δ it was necessary to further investigate the meaning and properties of this Δ .

Our first analytical investigation which is reported in a later section demonstrated that it was not at all necessary to consider a discrete process with Δ the size of the possible concentration jumps. The process can be considered as a continuous stochastic process with Δ entering as a scale parameter in the variance of the distribution of the continuous process. This produces a much more appealing result. One can now consider the discrete process and take things to the limit without changing the size of the parameter Δ . With this result the new interpretation says that the change in concentration has variance proportional to the stochastic parameter Δ but makes no restrictions on the minimum size of the degrading process. Δ is thus an inherent parameter for the process. It could conceivably be different for BOD and DO but large differences would not be likely.

The next step was to investigate by means of Stochastic Simulation the effects on Δ caused by random fluctuation in several of the input and hydraulic parameters. This study is presented in [7]. In essence that work ignored the stochastic models and assumed that the variability in concentration readings was due to random fluctuations in either the K rates or the loadings including the benthal demand. These rates and loads were given the variability normally encountered in their measurements and the effects were traced by simulated case studies. The result was that the effective Δ not only differed for BOD and DO but that they differed by a factor of 10. The data which has already been

analyzed indicates only a few percent discrepancy between the Δ values for BOD and DO. The obvious conclusion here is that Δ is not caused by random variations in the parameter but by the stochastic process itself as the Stochastic Model predicts.

Next it became important to determine what effect the various stream, estuary, hydraulic, loading, etc. parameters and constants had on the value of Δ . The study [10] demonstrated the effect of temperature and turbulence. An investigation was then made (see [11]) which ascertained the effect of the initial concentration level on the value of Δ . In laboratory experiments, it was found that the effect was significant. Therefore, it is clear that Δ should be made a function of as many parameters, constants, loads, etc. as can be incorporated into a realistic program.

The programs are given in the appendix with their documentation given in another section of this report. To find a predicting equation for Δ one must do two things. First, find the appropriate terms to use, and second, determine the optimal predicting equation. It is important to find the appropriate terms since data is usually only partially taken. That is, several possibly important parameters are not recorded or only an insufficient number of them are reported. It would be simple to write a program with all the important terms included if the program was never to be used with live data. The first stage suggested here surveys the type of data which is or will be taken and suggests a form for the predicting equation which is possible with that type of data. The data is analyzed as to how many values are available for including certain terms in the prediction equation. If there are not enough values, terms can be eliminated and a new analysis made. This is continued until the analysis says that there are sufficient data available for the prediction equation.

For the second stage the data is fit, by means of a standard least squares program, to a linear function

of the included terms. The included terms might be, for example, which station, temperature, flow velocity, concentration range, and BOD loading range. The resulting equation could then be used to predict Δ for future use at that station by putting in values for temperature, flow, concentration range and BOD loading range. This is done for the Ohio and the Potomac and included elsewhere in this report.

Thus this procedure uses present data from a stream or estuary and uses it to obtain an equation to predict future values of Δ for this same stream or estuary.

CONCLUSIONS

The present form of the Stochastic Model can handle load inputs, rate constants, velocity, temperature, benthic demands, land runoff, hydraulic parameters, geometry, and random pollution inputs, all of which may be time- and position-dependent. It can accurately predict the time-dependent mean concentration at any point in a stream or estuary. It can do this in a transient state condition as well as for the pseudo-steady state condition. It can also accurately predict the proportion of time that the concentrations will be above or below any given level. It can do all this for BOD and DO and even for nitrogen wastes provided no algae blooms develop. For that situation the model will have to be extended. The extension is not trivial but it can be done.

RECOMMENDATIONS

The success of the verifications of the model leads to four recommendations.

1. The model should be used whenever algae blooms are not prominent. The model can be used to determine the transient effect of a change in input load simply by putting that change in the program and watching it proceed in time. This can be used either to determine what effect a proposed change in input load will have

on the stream or estuary in both the transient and the steady state conditions. It can also be used to determine if a suspected violation has occurred by noting the effect on the waterway and ascertaining what changes might have caused it. This latter use was illustrated twice during the verification phase of this project. The model did not fit in the vicinity of Mill Creek in Cincinnati, Ohio. We ascertained that the large change in DO without a corresponding change in BOD could not have been simply the result of an increased BOD load. Most probably it was the effect of readily soluble pollutants, possibly caused by anaerobic decomposition and dumped at or near Mill Creek. This would have caused a DO drop before the next station could pick up any increase in BOD. In another instance three days of data had to be eliminated from the Potomac analysis. The DO values could not have resulted from the residual BOD loads upstream as reported. Evidently a major upstream source was shut down for three days and no record was made on the data presented us. The Stochastic Model detected these situations since it predicts values continuously. Values outside the usual ranges can be interpreted as a break in steady state conditions.

2. Although we like to think of the present Stochastic Model as being all useful it has one severe limitation. It cannot predict the effect of algae. This restriction can be eliminated with further effort. The basic model need not be changed--only extended. Several more terms could be put into the equations and the equations resolved.

3. It would be a worthwhile project to verify the prediction methods for Δ by considering data taken on the same estuary at different times. This might involve revising the prediction system and then verifying the revision on still more data. In any event this task would have to be accompanied by an efficient data collecting system.

4. This last recommendation pertains to water quality standards themselves. As we have seen, concentrations have natural fluctuations. It is unrealistic

to require a stream or estuary to have at least 5 ppm dissolved oxygen all the time. The standard should contain restrictions on the proportions of the time that concentrations can be outside preset limits. Although this can possibly be done even now using the Stochastic Model as a base, one must proceed cautiously. A standard is unrealistic if violations cannot be detected. The standard must be written in terms of sampling schemes. The sampling scheme must say how often, where and how many samples should be taken. The standard should say that if there are more than a specified number of samples outside specified limits then there is a standard violation. This type of standard is more realistic and enforceable.

RANDOM OR VARIABLE INPUTS

BACKGROUND

As pointed out earlier, the model developed by Custer and Krutchkoff for BOD and DO in estuaries simulates a continuous release of pollution Δ in each time interval δt . The first release is at $t_0=0$ and the last release is at $t_0=t$, where t is the time of interest. The probability of one of these releases being at location x after time t was obtained by using a random walk mechanism to generate difference equations which are then approximated in continuous time. Since the individual particles are independent it follows that the probability of a given concentration at location x after time t is the convolution of the probabilities for the individual particles.

To obtain a convolution, Custer and Krutchkoff assume that each unit of pollution behaves as an independent bernoulli random variable. If a given unit is at x after time t , a success is recorded; otherwise a failure is recorded. The probability of success, given that the pollution was released at step n_1 , is $u(m, n | n_1)$, where $u(m, n | n_1)$ is defined after equation (31). Let

$$p_k(m, n) = \Pr[k \text{ BOD units at location } m\delta x \text{ after time } n\delta t] \quad (53)$$

and

$$\tilde{p}_k(m, n) = \Pr[\text{OD concentration is } k\Delta \text{ at location } m\delta x \text{ after time } n\delta t]. \quad (54)$$

The above probability, $p_k(m, n)$ is a convolution of the individual bernoulli trials. The probability generating function (pgf) for $p_k(m, n)$ is given by

$$\begin{aligned} P(m, n, s) &= \sum_{k=0}^{\infty} p_k(m, n) s^k \\ &= \prod_{i=0}^n G_1(m, n, s) \end{aligned} \quad (55)$$

where

$G_i(m, n, s)$ is the pgf for $u(m, n|i)$.

Thus,

$$P(m, n, s) = \prod_{i=0}^n [1 - u(m, n|i) + u(m, n|i)s]. \quad (56)$$

Similarly, for OD

$$\begin{aligned} \tilde{P}(m, n, s) &= \sum_{k=0}^{\infty} p_k(m, n) s^k \\ &= \prod_{i=0}^n [1 - v(m, n|i) + v(m, n|i)s]. \end{aligned} \quad (57)$$

Where $v(m, n|i)$ is the probability that a unit of OD is at location $m\delta x$ after time $n\delta t$ given that the unit of BOD entered the estuary at n .

The probability of the system being in any particular state can be found by picking out the desired coefficients in $P(m, n, s)$ and $\tilde{P}(m, n, s)$.

The means and variances of the distribution given above can be obtained using the pgf and are given by

$$\text{MEAN (BOD state)} = \sum_{j=0}^n u(m, n|j) \quad (58)$$

$$\text{VAR (BOD state)} = \sum_{j=0}^n u(m, n|j) - \left(\sum_{j=0}^n (u(m, n|j))^2 \right) \quad (59)$$

$$\text{MEAN (OD state)} = \sum_{j=0}^n v(m, n|j) \quad (60)$$

and

$$\text{VAR (OD state)} = \sum_{j=0}^n v(m, n|j) - \left(\sum_{j=0}^n (v(m, n|j))^2 \right) \quad (61)$$

Custer and Krutchkoff obtain continuous approximations for $u(m, n|j)$ and $v(m, n|j)$ which allow the moments to be calculated more rapidly. These will be explained shortly.

DERIVATION

Suppose the input BOD into the estuary is not a constant uniform input as assumed by Custer and Krutchkoff, but enters in some random fashion. Let us assume, however, that the number of BOD units entering the estuary can be discretized into multiples of Δ units.

Since the input is random, it must enter the estuary at each point in time according to some discrete probability distribution. Let Y represent the random input and let $P[Y = y_i] = f_i$ have pgf $F(s)$ where i denotes the time of input.

Now define

$$P_{k_1}(m, n) = \Pr[k_1 \text{ of the } y_1 \text{ BOD units are at location } m\delta x \text{ after time } n\delta t | y_1 \text{ units enter at time } n_1] \quad (62)$$

Since each of the individual units released at the same time are independently and identically distributed, the probability $p_{k_1}(m, n)$ is a compound probability. Thus,

$$P_{k_1}(m, n) = \sum_{y_1=0}^{\infty} P[Y_1 = y_1] P[X_0 + X_1 + \dots + X_{y_1} = k_1] \quad (63)$$

where

X_j is the j th unit entering the estuary at time n_1 and is a bernoulli random variable.

Therefore, the pgf for $p_{k_1}(m, n)$ is given by

$$P_1(m, n, s) = F(G_1(s)) \quad (64)$$

where

$G_1(s)$ is the pgf for X_1 . The expected value of X_1 is $u(m, n | n_1)$ which Custer and Krutchkoff define as the probability that after n steps the unit of BOD is at

location $m\delta x$ given that the unit entered the estuary at step n_1 .

To find the final probability of k BOD units being at location $m\delta x$ after $n\delta t$ one must convolute the $p_{k_i}(m,n)$ for $i=0, \dots, n$. Using the convolution property of generating functions,

$$\begin{aligned} P(m,n,s) &= \prod_{i=0}^n P_i(m,n,s) \\ &= \prod_{i=0}^n F(G_i(s)) \\ &= \prod_{i=0}^n \sum_{j=0}^{\infty} f_j(G_i(s))^j. \end{aligned} \quad (65)$$

$P(m,n,s)$ is the pgf for $p_k(m,n)$ as defined previously with $k_0 + k_1 + \dots + k_n = k$. Since $G_i(s)$ is the pgf for bernoulli random variable,

$$P(m,n,s) = \prod_{i=0}^n \sum_{j=0}^{\infty} f_j [1 - u(m,n|i) + u(m,n|i)s]^j. \quad (66)$$

The probability of the system being in any particular state can be found by picking out the desired coefficients in $P(m,n,s)$.

A similar derivation can be made for oxygen deficit which yields,

$$\tilde{P}(m,n,s) = \prod_{i=0}^n \sum_{j=0}^{\infty} f_j [1 - v(m,n|i) + v(m,n|i)s]^j. \quad (67)$$

The complete distribution can thus be obtained at any point in time and space, but the time required is large for large values of n . The moments of the distribution are easily obtained and are now given.

MOMENTS OF THE RESULTING DISTRIBUTION

To find the moments for distribution of BOD and OD for any point in time and space it is possible to use the pgf. This immediately yields

$$\text{MEAN (BOD state)} = P'(m, n, 1) \quad (68)$$

$$\begin{aligned} \text{VAR (BOD state)} &= P''(m, n, 1) + P'(m, n, 1) \\ &\quad - (P'(m, n, 1))^2 \end{aligned} \quad (69)$$

$$\text{MEAN (OD state)} = \tilde{P}'(m, n, 1) \quad (70)$$

and

$$\begin{aligned} \text{VAR (OD state)} &= \tilde{P}''(m, n, 1) + \tilde{P}'(m, n, 1) \\ &\quad - (\tilde{P}'(m, n, 1))^2 \end{aligned} \quad (71)$$

Now let

$$\begin{aligned} E(Y_i) &= \lambda_i \\ E(X_i) &= u_i \quad i=0, 1, \dots, n \end{aligned} \quad (72)$$

where E represents the expected value and where the pgfs corresponding to Y_i and X_i are $F_i(s)$ and $G_i(s)$ respectively.

Using equation (65) and setting $n=0$, the moments for the BOD state are

$$\begin{aligned} \text{MEAN (BOD state)} &= P'(m, n, 1) \\ &= F'(G_0(1)) G'_0(1) \\ &= u_0 \lambda_0 \end{aligned} \quad (73)$$

$$\begin{aligned} \text{VAR (BOD state)} &= F'(G_0(1)) G''_0(1) - G_0(1) F''(G_0(1)) G'_0(1) \\ &\quad + F'(G_0(1)) G'_0(1) - (F'(G_0(1)))^2 (G'_0(1))^2 \\ &\quad + (G'_0(1))^2 F'(1) - (G_0(1))^2 F'(1) \end{aligned}$$

$$\begin{aligned}
&= F'_0(1) [G'_0(1) + G_0(1) - (G_0(1))^2] \\
&\quad + (G_0(1))^2 [F'_0(1) + F_0(1) - (F_0(1))^2] \\
&= \lambda_0 \text{VAR } X_0 + u_0^2 \text{VAR } Y_0 \quad (74)
\end{aligned}$$

For $n=1$

$$P(m, n, s) = F(G_0)F(G_1) \quad (75)$$

and

$$\begin{aligned}
\text{MEAN (BOD state)} &= F(G_0(1))F'(G_1(1))G'_1(1) \\
&\quad + F(G_1(1))F'(G_1(1))G'_0(1) \\
&= \lambda_1 u_1 + \lambda_0 u_0 \quad (76)
\end{aligned}$$

For notational convenience let $F_1 = F(G_1(1))$ and $G_1 = G'_1(1)$. Then

$$\begin{aligned}
\text{VAR (BOD state)} &= F_0 F'_1 G_1'' + F_0 G_1'^2 F'_1 \\
&\quad + F_1 G_1' F'_0 G'_0 + F_1 F'_0 G'_0 \\
&\quad + F_1 G_0'^2 F'_0 + F'_0 G'_0 F'_1 G_1 \\
&\quad + F'_1 G_1 + F'_0 G'_0 - F_1'^2 G_1^2 \\
&\quad - F_0'^2 G_0^2 - 2F'_1 G_1 F'_0 G'_0 \\
&\quad + F'_0 G_0'^2 - F'_0 G_0'^2 + F'_1 G_1^2 - F'_1 G_1^2 \\
&= F'_0 [G'_0 + G_0 - G_0^2] + F'_1 [G'_1 + G_1 - G_1^2] \\
&\quad + G_0^2 [F'_0 + F_0 - F_0^2] + G_1^2 [F'_1 + F_1 - F_1^2] \\
&= \lambda_0 \text{VAR } X_0 + \lambda_1 \text{VAR } X_1 + u_0^2 \text{VAR } Y_0 + u_1^2 \text{VAR } Y_1. \quad (77)
\end{aligned}$$

In general it can be shown that for any n

$$\text{MEAN (BOD state)} = \sum_{i=0}^n \lambda_i u(m, n | j) \quad (78)$$

and

$$\text{VAR (BOD state)} = \sum_{i=0}^n \lambda_1 \text{VAR} X_1 + \sum_{i=0}^n (u(m,n|i))^2 \text{VARY}_1. \quad (79)$$

Since X_1 is a bernoulli random variable with mean $u(m,n|i)$ the variance becomes

$$\begin{aligned} \text{VAR (BOD state)} = & \sum_{i=0}^n \lambda_1 u(m,n|i) + \sum_{i=0}^n (u(m,n|i))^2 \text{VARY}_1 \\ & - \sum_{i=0}^n \lambda_1 (u(m,n|i))^2. \end{aligned} \quad (80)$$

A similar derivation for oxygen deficit yields

$$\text{MEAN (OD state)} = \sum_{i=0}^n \lambda_1 v(m,n|i). \quad (81)$$

$v(m,n|i)$ is the probability of an OD particle being at location $m\delta t$ after time $n\delta t$ given that the BOD particle entered the estuary at time $i\delta t$. Also

$$\begin{aligned} \text{VAR (OD state)} = & \sum_{i=0}^n \lambda_1 v(m,n|i) + \sum_{i=0}^n (v(m,n|i))^2 \text{VARY}_1 \\ & - \sum_{i=0}^n \lambda_1 v(m,n|i)^2. \end{aligned} \quad (82)$$

CONTINUOUS APPROXIMATIONS

Numerical solutions for $u(m,n|i)$ and $v(m,n|i)$ can be obtained, but for small values of δt steady state solutions require an enormous amount of computer time. Custer and Krutchkoff, however, are able to obtain continuous approximations for $u(m,n|i)$ and $v(m,n|i)$ as $\delta t \rightarrow 0$. Let

$$u(m,n|i) \approx f(x,t|t_1) \delta x \quad (83)$$

$$v(m,n|i) \approx g(x,t|t_1) \delta x$$

Solutions for functions f and g were given previously.

Let the average increase in the BOD concentration at the source in time δt be $\lambda \Delta$ where λ is less than one.

Thus

$$\lambda \Delta = \frac{W \delta t}{A \delta x} \quad (84)$$

where W is the rate at which pollution enters the estuary and A is the cross sectional area. δx and δt are both small but consistent with

$$E = \frac{(\delta x)^2}{2 \delta t} \quad (85)$$

E is the diffusion coefficient. λ is the average number of BOD units of size Δ entering the estuary in a time interval δt and need not be preassigned since it depends on δt .

At time $i \delta t$ Y_i units enter the estuary. Where $Y_i = 1$ with probability p and $Y_i = 0$ with probability $1-p$. As $\delta t \rightarrow 0$, $p \rightarrow 0$. Making appropriate substitutions yields

$$\text{MEAN (BOD state)} = \frac{W}{A \Delta \lambda} \sum_{i=0}^n E(Y_i) f(x, t | t_i) \delta t. \quad (86)$$

Letting $\delta t \rightarrow 0$ yields

$$\text{MEAN (BOD state)} = \frac{W}{A \Delta} \int_0^t \rho(\tau) f(x, t | \tau) d\tau \quad (87)$$

where

$$\rho(\tau) = \frac{E(Y_i)}{\lambda} \text{ at time } \tau.$$

If for example $E(Y_i) = \lambda$ for all i then

$$\text{MEAN (BOD state)} = \frac{W}{A \Delta} \int_0^t f(x, t | \tau) d\tau \quad (88)$$

which is the result obtained by Custer and Krutchkoff. Also

$$\text{VAR (BOD state)} = \frac{W}{A \Delta \lambda} \sum_{i=0}^n E(Y_i) f(x, t | t_i) \delta t$$

$$+ \frac{W^2}{A^2 \Delta^2 \lambda^2} \sum_{i=0}^n \text{VAR}_i f^2(x, t | t_i) (\delta t)^2$$

$$\frac{W^2}{A^2 \Delta^2 \lambda^2} \sum_{i=0}^n E(Y_i) f^2(x, t | t_i) (\delta t)^2. \quad (89)$$

Since Y_i is defined as a bernoulli random variable

$$\text{VAR (BOD state)} = \frac{W}{A \Delta} \sum_{i=0}^n E(Y_i) f(x, t | t_i) \delta t$$

$$- \frac{W^2}{A^2 \Delta^2 \lambda^2} \sum_{i=0}^n (E Y_i)^2 f^2(x, t | t_i) (\delta t)^2, \quad (90)$$

Since EY_i is the same order of magintude as λ when $\delta t \rightarrow 0$ the second term vanishes and the variance becomes

$$\text{VAR (BOD state)} = \frac{W}{A \Delta} \int_0^t \rho(\tau) f(x, t | \tau) d\tau. \quad (91)$$

If for example $E(Y_i) = \lambda$ for all i then

$$\text{VAR (BOD state)} = \frac{W}{A \Delta} \int_0^t f(x, t | \tau) d\tau \quad (92)$$

which is the result previously derived by Custer and Krutchkoff.

Similar derivations hold for OD states such that

$$\text{MEAN (OD state)} = \frac{W}{A \Delta} \int_0^t \rho(\tau) g(x, t | \tau) d\tau \quad (93)$$

and

$$\text{VAR (OD state)} = \frac{W}{A \Delta} \int_0^t \rho(\tau) g(x, t | \tau) d\tau. \quad (94)$$

Once again Custer and Krutchkoff's results are obtained when $E(Y_i) = \lambda$ for all i .

Letting $\mu(x, t)$ and $\sigma^2(x, t)$ represent the BOD mean and variance, respectively and noting that the level of pollution is $\lambda \Delta$ times the state one obtains,

$$\mu(x, t) = \frac{W}{A} \int_0^t \alpha(\tau) f(x, t | \tau) d\tau \quad (95)$$

where

$$\alpha(\tau) = E(Y_1) \text{ at time } \tau \quad (96)$$

and

$$\sigma^2(x, t) = \lambda \Delta \mu(x, t). \quad (97)$$

Similarly, if $\underline{\mu}(x, t)$ and $\underline{\sigma}^2(x, t)$ denote the mean and variance for $\underline{OC}$, one obtains

$$\underline{\mu}(x, t) = \frac{W}{A} \int_0^t \alpha(\tau) g(x, t | \tau) d\tau \quad (98)$$

and

$$\underline{\sigma}^2(x, t) = \lambda \Delta \underline{\mu}(x, t). \quad (99)$$

If once again $E(Y_1) = \lambda$ for all t ,

$$\mu(x, t) = \frac{\lambda W}{A} \int_0^t f(x, t | \tau) d\tau \quad (100)$$

$$\sigma^2(x, t) = \lambda \Delta \mu(x, t) = \frac{\lambda^2 W \Delta}{A} \int_0^t f(x, t | \tau) d\tau \quad (101)$$

$$\underline{\mu}(x, t) = \frac{\lambda W}{A} \int_0^t g(x, t | \tau) d\tau \quad (102)$$

and

$$\underline{\sigma}^2(x, t) = \lambda \Delta \underline{\mu}(x, t) = \frac{\lambda^2 W \Delta}{A} \int_0^t g(x, t | \tau) d\tau \quad (103)$$

which are the results previously obtained by Custer and Krutchkoff except for the extra parameter. When $E(Y_1)$ is not constant but allowed to vary in time, then the appropriate final equations are (95), (97), (98), and (99). The important things to notice are that:

1. The distribution about the mean effect $E(Y_1)$ does not enter into these equations. This variability disappeared when the continuous approximation was made.

2. The variance is $\lambda \Delta$ times the mean. However, $\lambda \Delta$ can be considered the Δ for the process. This result is called the Poisson Approximation.

THE SEGMENTED ESTUARY MODEL OUTPUT-INPUT MODEL

In Moushegian and Krutchkoff [55] it was found that a segmented stream solution could be obtained by using the probability output of one segment as the probability input of the next segment. Although an estuary is far more complicated than a stream, this simple approach might produce approximate solutions which could be used for a segmented estuary. This output-input approach is described here.

Let us say that the pollution loading function is given by $W(t)$. Thus $W(t)\delta t$ is the amount of pollution entering the estuary in time δt . If the fluid in the estuary moves a distance δx in time δt then the concentration entering the estuary in time δt is given by

$$\text{Concentration} = \frac{W(t)\delta t}{A\delta x} \quad (104)$$

where A is the cross sectional area of the estuary. In order to put this into the framework of the Custer and Krutchkoff model we assume that this concentration is measured in multiples of Δ and therefore,

$$\lambda\Delta = \frac{W(t)\delta t}{A\delta x} \quad (105)$$

where λ is the average number of concentration units of size Δ entering the estuary in time δt . Of course δt and δx are related by the relation

$$E = \frac{(\delta x)^2}{2\delta t} \quad (106)$$

where E is the diffusion constant.

If in equations (87) and (93) we use $W(t)$ for $W\rho(t)/\lambda$ then we obtain

$$\text{MEAN (BOD state)} = \frac{\lambda}{A\Delta} \int_0^t W(t)f(x,t|\tau)d\tau \quad (107)$$

and

$$\text{MEAN (OD state)} = \frac{\lambda}{A\Delta} \int_0^t W(t) g(x, t | \tau) d\tau \quad (108)$$

where $f(x, t | \tau)$ and $g(x, t | \tau)$ are given in equations (41) and (42).

Let us say that at x_0 there was a source with input function $W_1(t)$. Let us assume further that the first segment extended from x_0 to x_1 . Then the mean state output for BOD at x_1 is given by

$$M(x_1, t) = \frac{\lambda}{A_1 \Delta} \int_0^t W_1(t) f_1(x_1, t | \tau) d\tau \quad (109)$$

where the subscript 1 on f indicates that all the parameters and constants in f are for the first segment. A similar result holds for OD. Now the mean concentration is given by

$$m(x_1, t) = \Delta M(x_1, t). \quad (110)$$

For the second segment, which we can assume extends from x_1 to x_2 , we know that the concentration is given by

$$m(x_1, t) = \frac{W_2(t) \delta t}{A_2 \delta x} \quad (111)$$

with δt and δx now related by

$$E_2 = \frac{(\delta x)^2}{2\delta t} \quad (112)$$

where E_2 is the diffusion constant of the second segment which could conceivably differ from the constant for the first segment. It should also be clear that for any instant of time

$$U_2(t) = \delta x / \delta t \quad (113)$$

where $U_2(t)$ is the velocity function for the fluid in the second segment. Therefore,

$$W_2(t) = m(x_1, t) A_2 U_2(t). \quad (114)$$

Using this we obtain the mean BOD state at x_2 to be given by

$$m(x_2, t) = \frac{\lambda}{\Delta} \int_0^t m(x_1, \tau) U_2(t) f_2(x_2, t | \tau) d\tau \quad (115)$$

with a similar result for OD.

At this point it will pay to write out equation (115) in detail. This provides

$$m(x_2, t) = \frac{\lambda^2}{\Delta A_1} \int_0^t \frac{U_2(\tau)}{2\sqrt{E\pi(t-\tau)}} \left[\int_0^\tau \frac{W_1(\xi)}{2\sqrt{E\pi(\tau-\xi)}} \exp\left\{-\left(x_1 - \int_\xi^\tau U_1(s) ds\right)^2 - K_1(\tau-\xi)\right\} d\xi \right] \exp\left\{-\left(x_2 - \int_\tau^t U_2(s) ds\right)^2 - K_2(t-\tau)\right\} d\tau. \quad (116)$$

The corresponding equation for OD is given by

$$\begin{aligned} m(x_2, t) = & \frac{\lambda^2}{\Delta A_1} \int_0^t \frac{K_1 U_2(\tau)}{2(K_2 - K_1)\sqrt{E\pi(t-\tau)}} \\ & \left[\int_0^\tau \frac{K_1 U_1(\xi)}{2(K_2 - K_1)\sqrt{E\pi(\tau-\xi)}} \exp\left\{-\left(x_1 - \int_\xi^\tau U_1(s) ds\right)^2\right\} \left[\exp\{-K_1(\tau-\xi)\} \right. \right. \\ & \left. \left. - \exp\{-K_2(\tau-\xi)\} \right] d\xi \right] \exp\left\{-\left(x_2 - \int_\tau^t U_2(s) ds\right)^2\right\} \left[\exp\{-K_1(t-\tau)\} \right. \\ & \left. - \exp\{-K_2(t-\tau)\} \right] d\tau. \quad (117) \end{aligned}$$

These equations are not simple equations, but they can be solved numerically by computer. They are double integrations and their solution requires a good deal of computing time. Therefore, before using the solutions as obtained from the computer programs, it was important to check to see if they gave the correct answers. This

could be done by a means used in the work of Moushegian and Krutchkoff [55]. The technique is to assume a constant input at x_0 and solve for the mean values at x_2 in two ways: first, by using the unsegmented formulas already developed and secondly by using equations (116) and (117) assuming some arbitrary segmenting point x_1 .

Unfortunately, the two solutions obtained at point x were significantly different. Unlike the situation for a stream, the fact that probabilities are used for both output and input functions could not compensate for the feedback necessary from the succeeding sections in an estuary. The magnitude of the discrepancy, even in this simple test, made it clear that the output-input approach could not be used as an approximate solution to the segmented estuary problem.

The fact that this procedure is not theoretically sound is easily seen with this following example. Assume that there is a constant input W at x_0 . After a time the concentration at x_0 is made up of two parts W and the residual effect of the previous inputs. This result is obtained by the Custer and Krutchkoff model. That is, the concentration at x_0 is significantly larger than would be obtained by using W alone. On the other hand the output at point x_1 is the total concentration at that point at any time. If this is used as the input of the next segment at x_1 and the equations resolved then the net concentration at x_1 would be the sum of the output from the first segment plus the residual concentration. However, the output of segment one is the total concentration at x_1 . Thus the procedure cannot even provide the proper answer at the point x_1 .

Since the Output-Input extension to the Custer and Krutchkoff model could not provide even an approximate solution to the segmented estuary problem a new model had to be derived.

DEVELOPMENT OF THE NEW STOCHASTIC MODEL

The model developed by Custer and Krutchkoff, [14], describes the stochastic nature of BOD and OD in an estuary but with the limitation that in order to get an analytic solution the process coefficients were held constant. Here a stochastic model for BOD and OD is developed in which the process coefficients (K_1 , K_2 , E , V_t , etc.) are functions of position in the estuary and, if necessary, functions of tidal phase. The model which is developed here is more than a segmented model in that the assumption of constant coefficients within a segment has been bypassed and a model is developed which describes the system parameters as they actually occur.

The development will, in general, follow that of the previously discussed Custer and Krutchkoff model. Units of pollution and dissolved oxygen are visualized as taking a nonconservative walk in the estuary. In each time interval δt a unit of BOD can either move one unit δx to the left (upstream) with probability $q(x,t)$, one unit δx to the right (downstream) with probability $p(x,t)$, or be biologically utilized with probability $r(x,t)$, such that $p(x,t) + q(x,t) + r(x,t) = 1.0$. These probabilities include the mean velocity of the tidal excursion. On decomposition a unit of BOD becomes a unit of OD and this OD unit continues the random walk until it is eliminated by reaeration from the atmosphere above the estuary or until its walk carries it permanently outside of the part of the estuary which is of interest. An important property of this random walk is that one unit of BOD or OD is not affected by any other unit. Thus the units are statistically independent.

With this foundation, difference equations are formulated which give the joint probability that a unit of BOD (or OD) will be at a point x in the estuary after any time t , given that the unit was introduced at the origin such as at a Sewage Treatment Plant, (STP) at time t_0 . Recall that the walk takes place in steps of size δx , so that the probabilities for any x which is not a multiple of δx will be zero. The quantities $p(x,t)$, $q(x,t)$, and $r(x,t)$ can be determined from the

physical properties of the estuary. For example, see equations (28), (29), and (30).

The unit of BOD used in the above discussion is the amount of BOD material needed to increase the concentration of a cross sectional sheet in the estuary with width δx by an amount Δ . Δ is a measured stochastic coefficient which is set by the physical, chemical, and biological properties of the estuary by methods given later. This discretizing of concentration is done to make the mechanism a stochastic process but is not a limitation as was pointed out in the INTRODUCTION. The total concentration due to many units of BOD occurs in states, which correspond to integer multiples of Δ . The states are determined by dividing the concentration by Δ , or if the state is known, concentration is determined by multiplying the state number by Δ .

THE DIFFERENCE EQUATIONS

Difference equations are used to determine the probabilities of a given BOD (or OD) unit being at a given location at a given time. Let $u(m,n)$ be the probability that after n steps the unit of BOD is at location $m\delta x$. The total time lapse t is $n\delta t$. The unit of BOD can be at location $m\delta x$ after n steps in either of two ways:

1. At time $(n-1)\delta t$ it is at location $(m-1)\delta x$ and takes a positive step (moves down the estuary),
2. At time $(n-1)\delta t$ it is at location $(m+1)\delta x$ and takes a backward step.

Thus,

$$u(m,n+1) = u(m-1,n)p((m-1)\delta x,n\delta t) + u(m+1,n)q((m+1)\delta x,n\delta t) \quad (118)$$

where

$$m \in (-\infty, \infty) \text{ and } n \in (0, \infty)$$

which are equivalent to

$$-\infty < x < \infty \text{ and } 0 \leq t < \infty .$$

As mentioned above the quantities $p(m\delta x, n\delta t)$, $q(m\delta x, n\delta t)$, and $r(m\delta x, n\delta t)$ can be determined from the physical properties of the estuary. Techniques have been developed by Einstein and others to describe the behavior of a particle placed in a medium in which it is exposed to a large number of random forces. The forces acting on the particle can be summarized into two components: the symmetric random forces described as diffusion and an asymmetric drift which is in this case due to velocity. This process is usually called the "diffusion" process. The classical problems in the diffusion process have been concerned with conservative particles. In our problem, however, there is a non-zero probability that the particle will be absorbed. These techniques provide a method by which the $p(x, t)$ and $q(x, t)$ can be determined. They provide

$$p(x, t) = (1 - K_d(x, t)\delta t)/2 + \frac{U(x, t)}{2} \frac{\delta t}{\delta x} \quad (119)$$

$$q(x, t) = (1 - K_d(x, t)\delta t)/2 - \frac{U(x, t)}{2} \frac{\delta t}{\delta x} \quad (120)$$

and

$$r(x, t) = K_d(x, t)\delta t \quad (121)$$

where

- $K_d(x, t)$ is the coefficient for the decrease of BOD by all processes, including biological utilization and all non-oxygen-consuming processes, i.e. $K_d(x, t) = K_1(x, t) + K_3(x, t)$
- $K_1(x, t)$ is the coefficient for biological utilization.
- $K_3(x, t)$ is the coefficient of all non-oxygen-consuming processes.
- $U(x, t)$ is the velocity of the water in the estuary.

The values of δx and δt used must remain consistent with the following relationship

$$\frac{(\delta x)^2}{\delta t} = 2E(x,t) \quad (122)$$

where $E(x,t)$ is the diffusion coefficient.

The initial conditions for the difference equation are as follows

$$\begin{aligned} U(0, n_0) &= 1.0 \\ U(m, n_0) &= 0 && \text{For all } m \neq 0 \\ U(m, n) &= 0 && \text{For all } n < n_0. \end{aligned} \quad (123)$$

Notice that $p(x,t) + q(x,t) + r(x,t) = 1.0$ in equations (119), (120), and (121) to meet the previously mentioned restriction on the behavior of the BOD particle, e.g. if the particle is not absorbed it must take a positive or a negative jump.

Recall now that a unit of OD is created when a unit of BOD is absorbed. Let $v(m,n)$ be the probability that a unit of OD is at location $m\delta x$ after time $n\delta t$. The probability of a forward step is $p(x,t)$, or a backward step is $q(x,t)$, and of absorption is $r(x,t)$.

The OD unit could be at location $m\delta x$ at time $n\delta t$ in three possible ways

1. By being at $(m-1)\delta x$ at time $(n-1)\delta t$ and taking a forward step
2. By being at $(m+1)\delta x$ at $(n-1)\delta t$ and taking a backward step.
3. By a unit of BOD at $m\delta x$ and $(n-1)\delta t$ being absorbed.

Thus,

$$\begin{aligned} v(m, n+1) &= v(m-1, n) \tilde{p}((m-1)\delta x, n\delta t) \\ &+ v(m+1, n) \tilde{q}((m+1)\delta x, n\delta t) + u(m, n) K_1(x, t) \delta t \end{aligned} \quad (124)$$

where

$$m \in (-\infty, \infty)$$

and

$$n \in [0, \infty).$$

The probabilities are specified by:

$$\tilde{p}(x,t) = (1-K_2(x,t)\delta t)/2 + \frac{U(x,t)}{2} \frac{\delta t}{\delta x} \quad (125)$$

$$\tilde{q}(x,t) = (1-K_2(x,t)\delta t)/2 - \frac{U(x,t)}{2} \frac{\delta t}{\delta x} \quad (126)$$

and

$$\tilde{r}(x,t) = K_2(x,t)\delta t \quad (127)$$

where $K_2(x,t)$ is the coefficient of reaeration.

The initial condition is given by, $v(m,n) = 0$ for all m and $n < n_0$.

The two difference equations, (118) and (124), could be solved iteratively, but this type solution is quite time consuming. The two equations would have to be solved for each unit of BOD introduced into a 20-mile estuary for at least twenty days in order to reach steady state. Then all these individual particle probabilities would have to be convoluted to obtain the final result. Also it should be noticed that the terms $u(x,t)$ and $v(x,t)$ are probabilities for one unit of BOD being at x at time t given that the unit was introduced at time t_0 . Thus $u(x,t)$ is really the conditional probability $u(x,t|t_0)$. The t_0 is important for two reasons: first, there must be a simple way to distinguish when more than one particle is present, and second, the probabilities depend on t_0 , i.e. two particles with the same elapsed time in the estuary usually have different probabilities if they were introduced at different phases in the tidal cycle.

CONTINUOUS LIMIT FOR DIFFERENCE EQUATIONS

Since the pollution flow, absorption, etc. of BOD in an estuary are actually continuous processes, a Taylor's expansion will be made on the two difference equations (118) and (124) and the limits taken as $\delta x \rightarrow 0$. As $\delta x \rightarrow 0$ the discrete probability mass function $u(x, t|t_0)$ and $v(x, t|t_0)$ will approach continuous probability density functions denoted by $f(x, t|t_0)$ and $g(x, t|t_0)$, respectively. The difference equations (118) and (124) can be rewritten with the new notation as

$$f(x, t + \delta t) = f(x - \delta x, t|t_0)p(x - \delta x, t) + f(x + \delta x, t|t_0)q(x + \delta x, t) \quad (128)$$

and

$$g(x, t + \delta t|t_0) = g(x - \delta x, t|t_0)p(x - \delta x, t) + g(x + \delta x, t|t_0)q(x + \delta x, t) + f(x, t|t_0)K_1(x, t)\delta t \quad (129)$$

Expanding equation (128) in a truncated Taylor's series about (x, t) yields

$$\begin{aligned} f(x, t|t_0) + \delta t \frac{\partial f}{\partial t} + \frac{(\delta t)^2}{2} \frac{\partial^2 f}{\partial t^2} + o(\delta t^3) = \\ [f(x, t|t_0) - \delta x \frac{\partial f}{\partial x} + \frac{(\delta x)^2}{2} \frac{\partial^2 f}{\partial x^2} + o(\delta x^3)] [p(x, t) - \delta x \frac{\partial p}{\partial x} + \frac{(\delta x)^2}{2} \frac{\partial^2 p}{\partial x^2} \\ + o(\delta x^3)] + [f(x, t|t_0) + \delta x \frac{\partial f}{\partial x} + \frac{(\delta x)^2}{2} \frac{\partial^2 f}{\partial x^2} + o(\delta x^3)] [q(x, t) + \delta x \frac{\partial q}{\partial x} \\ + \frac{(\delta x)^2}{2} \frac{\partial^2 q}{\partial x^2} + o(\delta x^3)] \quad (130) \end{aligned}$$

Carrying out multiplication on the right side of equation (130) and neglecting terms of $o(\delta x^3)$ or smaller, $f(x, t|t_0)$ will be denoted by f .

$$\text{right hand side} = fp - \delta x p \frac{\partial f}{\partial x} + \frac{(\delta x)^2}{2} p \frac{\partial^2 f}{\partial x^2} - \delta x f \frac{\partial p}{\partial x} + \frac{(\delta x)^2}{2} \frac{\partial f}{\partial x} \frac{\partial p}{\partial x}$$

$$+ \frac{(\delta x)^2}{2} f \frac{\partial^2 p}{\partial x^2} + f q + \delta x q \frac{\partial f}{\partial x} + \frac{(\delta x)^2}{2} q \frac{\partial^2 f}{\partial x^2} + \delta x f \frac{\partial q}{\partial x} + \frac{(\delta x)^2}{2} \frac{\partial f}{\partial x} \frac{\partial q}{\partial x} \\ + \frac{(\delta x)^2}{2} f \frac{\partial^2 q}{\partial x^2} + o(\delta x^2) . \quad (131)$$

Regrouping the entire equation and dividing by δt yields,

$$\frac{\partial f + \delta t}{\partial t} \frac{\partial^2 f + o(\delta t^2)}{2 \partial t^2} = f \left[\frac{p+q-1+\delta x}{\delta t} \frac{\partial q - \partial p}{\partial x} \right] \\ + \frac{(\delta x)^2}{2 \delta t} \left[\frac{\partial^2 p + \partial^2 q}{\partial x^2} \right] + \frac{\partial f}{\partial x} \left[\frac{\delta x(q-p) + (\delta x)^2}{\delta t} \frac{\partial p + \partial q}{\partial x} \right] + \frac{\partial^2 f}{\partial x^2} \left[\frac{(\delta x)^2}{2 \delta t} (p+q) \right] \\ + o(\delta x^2) . \quad (132)$$

There is a reason for the particular way in which these terms were grouped. Rearranged and modified forms of the $p(x,t)$, $q(x,t)$, etc. definitions can now be substituted into the differental equations. Recall that

$$a) \frac{(\delta x)^2}{2 \delta t} = E$$

$$b) q(x,t) + p(x,t) = 1 - K(x,t) \delta t$$

$$c) -K_1(x,t) = (q-p-1)/\delta t$$

$$d) \frac{\partial q + \partial p}{\partial x \partial x} = \frac{-\partial K_1}{\partial x} \delta t$$

$$e) \frac{\partial^2 q + \partial^2 p}{\partial x^2 \partial x^2} = \frac{-\partial^2 K_1}{\partial x^2} \delta t$$

$$f) p(x,t) - q(x,t) = U(x,t) \frac{\delta t}{\delta x}$$

$$g) -U(x,t) = (q-p) \frac{\delta x}{\delta t}$$

and

$$h) \frac{-\partial p + \partial q}{\partial x \partial x} = \frac{-\partial U \cdot \delta t}{\partial x \delta x}$$

Substituting these expressions into equation (132) yields

$$\begin{aligned} \frac{\partial f + \delta t}{\partial t} \frac{\partial^2 f + o(\delta t)}{2 \partial x^2} &= f \left\{ -K_d - \frac{\partial U}{\partial x} - E \frac{\partial^2 K_d}{\partial x^2} \delta t \right\} \\ + \frac{\partial f}{\partial x} \left\{ -U - 2E \frac{\partial K_d}{\partial x} \delta t \right\} + \frac{\partial^2 f}{\partial x^2} \{ E(1 - K_d \delta t) \} + o(\delta x) \end{aligned} \quad (133)$$

Taking the limit as δt and $\delta x \rightarrow 0$ yields:

$$\frac{\partial f}{\partial t} = -K_d f - f \frac{\partial U}{\partial x} - U \frac{\partial f}{\partial x} + E \frac{\partial^2 f}{\partial x^2} \quad (134)$$

or

$$\begin{aligned} \frac{\partial f(x,t|t_0)}{\partial t} &= E(x,t) \frac{\partial^2 f}{\partial x^2} - U(x,t) \frac{\partial f}{\partial x} \\ - f \frac{\partial U(x,t)}{\partial x} - K_d f. \end{aligned} \quad (135)$$

This is the Fokker-Planck Equation for the continuous diffusion processes but with extra terms to account for the nonconservative nature of our process.

A similar derivation of $g(x,t|t_0)$ results in the following equation

$$\begin{aligned} \frac{\partial g(x,t|t_0)}{\partial t} &= E(x,t) \frac{\partial^2 g}{\partial x^2} - U(x,t) \frac{\partial g}{\partial x} \\ - (K_2(x,t) + \frac{\partial U(x,t)}{\partial x}) g + K_1(x,t) f. \end{aligned} \quad (136)$$

Notice that f is coupled into this equation to account for the transformation of BOD to OD. Thus when a unit of BOD is introduced into the estuary, its behavior

is described by equation (135) until it is biologically utilized. Then it becomes a unit of OD and follows equation (136).

Recall that the system under consideration is a representation of a very thin cross sectional sheet of an estuary which BOD (or OD) equation, describes the probability of a particular particle being at any position, x , at any time, t . A plot of $f(x,t)$ for several different times would look like Figure 7.

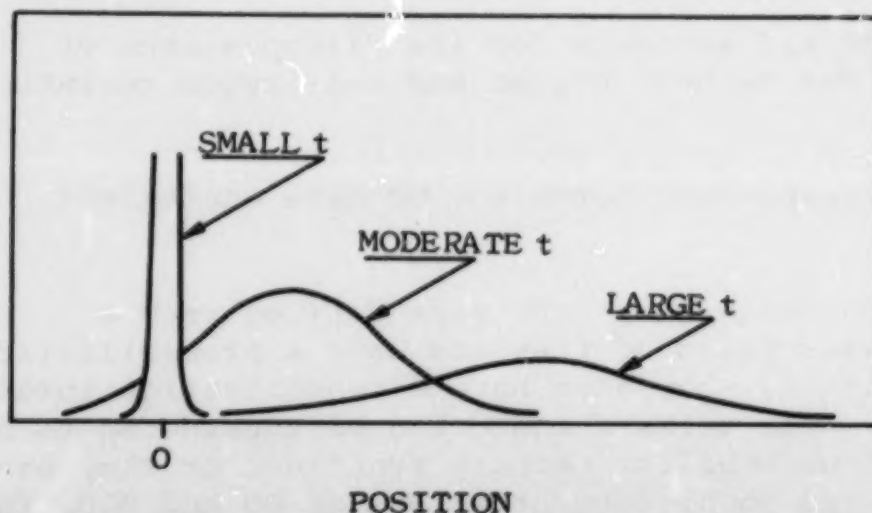


FIGURE 7 THE PROBABILITY DENSITY OF A UNIT OF BOD AT VARIOUS TIMES

At small time all the probability is centered near the STP outfall, x_0 . As time increases the probability spreads out due to diffusion, migrates down stream due to fresh water flow, and the area under the curve decreases due to biological utilization. At large time the processes of spreading out, migration, and biological utilization continue. The effect of each of the terms can be seen in the figure. A more detailed description is given below.

The expression $E(x,t)\partial^2 f/\partial x^2$ is the net difference between the rate of diffusion of probability into the differential sheet and the rate of diffusion out of the sheet. That is the term $E\partial^2 f/\partial x^2$ is the rate of increase of f due to diffusion.

The term $U(x,t)\partial f/\partial x$ accounts for the effect of bulk flow, both fresh water and tidal flow. The amount of probability being swept into the sheet by bulk flow is different by $-\partial f/\partial x$ from the amount being swept out. Then $-U\partial f/\partial x$ is the rate of increase in f due to bulk flow.

The term $f\partial u/\partial x$ is a correction for compressibility of the fluid in question. Since water is incompressible this term has been neglected.

The term $K_d f$ accounts for the disappearance of BOD units due to both oxygen and non-oxygen consuming process

The corresponding terms for OD have equivalent meanings.

Although these equations were derived from a probabilistic point of view and have a probabilistic interpretation, they also have a concentration interpretation. The terms f and g can be considered to be continuous probability density functions or they can be considered to be concentrations of OD and BOD. That is, where probability is high average concentrations must be high. This is an extremely important property and will be discussed in detail at the end of the following section. In addition, a derivation of a general diffusion equation from a concentration point of view will be made in a later section of this work.

CONTINUOUS SOURCE

Equations (135) and (136) are in the probabilistic point of view differential equations for the continuous probability density functions for a unit of BOD and OD, respectively, given that the unit of BOD was released into the estuary at time, t_0 . If δt , the time between the introduction of successive BOD units, is made small the pollution input will approach a continuous source. Then the probability of concentration being at a specified level at a certain time and position can be determined by convoluting the probabilities of the

individual units. The convolution can be derived by considering the process as a series of individual bernoulli trials. A given unit being at x at time t will be considered a success, where x and t are the position and time of interest. Reverting temporarily to the discrete notation of equations (53) and (59), denote the probability of success for the release at step n_1 by $u(m, n | n_1)$, where $n = x/\delta x$ and $n = t/\delta t$. Let $p_k(m, n) = \text{Pr}[k \text{ BOD units are at location } m\delta x \text{ after time } n\delta t]$ and $\tilde{p}_k(m, n) = \text{Pr}[k \text{ OD units at } m\delta x \text{ after time } n\delta t]$. Recall that k OD units correspond to a concentration of $k\Delta$.

Let

$$P(m, n, s) = \sum_{k=0}^{\infty} p_k(m, n) s^k \quad (137)$$

and

$$\tilde{P}(m, n, s) = \sum_{k=0}^{\infty} \tilde{p}_k(m, n) s^k. \quad (138)$$

Then

$$\begin{aligned} P(m, n, s) &= \prod_{i=0}^n [(1 - u(m, n | i)) s^0 + u(m, n | i) s^1] \\ &= \prod_{i=0}^n [(1 - u(m, n | i)) + u(m, n | i) s] \end{aligned} \quad (139)$$

and

$$\tilde{P}(m, n, s) = \prod_{i=0}^n [(1 - v(m, n | i)) + v(m, n | i) s] \quad (140)$$

$P(m, n, s)$ and $\tilde{P}(m, n, s)$ are respectively probability generating functions for the probabilities of BOD and OD concentrations being in their various states. The probability of the system being in any particular state can be found by picking off the desired coefficients of $P(m, n, s)$ and $\tilde{P}(m, n, s)$. The complete set of probabilities can be determined by multiplying out equations (139) and (140). However, the values for the mean and variance can be evaluated without resorting to this time consuming procedure. The mean and variance of a distribution with generating functions $F(s)$ are given by

$$E(k) = F'(s) |_{s=1} \quad (141)$$

and

$$\text{Var}(k) = F''(s) \Big|_{s=1} + F'(s) \Big|_{s=1} - (F'(s))^2 \Big|_{s=1}. \quad (142)$$

For this case

$$P'(m,n,s) = \sum_{j=0}^n u(m,n|j) \prod_{\substack{i=0 \\ i \neq j}}^n [(1-u(m,n|i)) + u(m,n|i)s] \quad (143)$$

and

$$P'(m,n,s) = \sum_{j=0}^n u(m,n|j) \sum_{\substack{k=0 \\ k \neq j}}^n u(m,n|k) \cdot$$

$$\prod_{\substack{i=0 \\ i \neq k \\ i \neq j}}^n [1-u(m,n|i) + u(m,n|i)s]. \quad (144)$$

Therefore,

$$\text{MEAN (BOD state)} = \sum_{j=0}^n u(m,n|j) \quad (145)$$

and

$$\text{VAR (BOD state)} = \sum_{j=0}^n u(m,n|j) - \sum_{j=0}^n (u(m,n|j))^2. \quad (146)$$

Similarly for OD

$$\text{MEAN (OD state)} = \sum_{j=0}^n v(m,n|j) \quad (147)$$

and

$$\text{VAR (OD state)} = \sum_{j=0}^n v(m,n|j) - \sum_{j=0}^n (v(m,n|j))^2. \quad (148)$$

Once again allow δt and hence δx to become small, consistent with $(\delta x)^2/\delta t = 2E(x,t)$, such that the process

approaches being continuous. Thus there will be a very large number of both BOD (or OD) units and of possible positions. Since there will be a very large number of possible positions, the probability, $u(m,n|j)$ (or $v(m,n|j)$) of any individual BOD (or OD) unit being in a given position will be very small. Hence as δt becomes small $u(m,n|j)^2$ (or $v(m,n|j)^2$) become very small and

$$\text{VAR (BOD state)} \rightarrow \sum_{j=0}^n u(m,n|j) \quad (149)$$

and

$$\text{VAR (OD state)} \rightarrow \sum_{j=0}^n v(m,n|j) \quad (150)$$

which equal the mean BOD and OD states. Thus, the mean and variance of the BOD and OD state distribution are equal, after the convolution operation has been carried out. Not only do the state distributions have equal mean and variance but these distributions can be shown to be poisson.

B. O. Koopman [48] gives necessary and sufficient conditions for a set of bernoulli trials (with probabilities of success not necessarily equal) to converge to a poisson distribution. Let $P(k) = \text{Pr}[X=k]$ where X is a poisson random variable with mean m . That is $P(k)$ is the probability of BOD being in the k th state assuming that the pollution is poisson distributed. Let

$$P_n(k) = \text{Pr}[Y = k, Y = \sum_{i=1}^n y_i] \quad (151)$$

where y_i is the outcome of the i th bernoulli trial, $P_n(k)$ is the probability that k of the n units of BOD are at x at time t . The mean of $P_n(k)$ is $p(n)$. Koopman's theorem states that

$$\lim_{n \rightarrow \infty} P_n(k) = P(k) \quad (152)$$

or the bernoulli becomes a poisson distribution if and only if

$$a) \lim_{n \rightarrow \infty} m(n) = m \quad (153)$$

and

$$b) \lim_{n \rightarrow \infty} \max_{1 \leq i \leq n} P_{n,i} = 0 \quad (154)$$

where $P_{n,i}$ is the probability of success on the i th trial of the n th set.

For condition (b) as n , the number of BOD units, approaches infinity, δt and the distance between adjacent positions both approach zero. Then

$$\begin{aligned} \lim_{n \rightarrow \infty} \max_{1 \leq i \leq n} P_{n,i} &= \lim_{n \rightarrow \infty} \max_{1 \leq i \leq n} u(m, n|i) \\ &= \lim_{\delta x \rightarrow 0} \max_{1 \leq i \leq n} f(x, t|i) \delta x = 0. \end{aligned} \quad (155)$$

Thus satisfying condition b) for all finite $f(x, t|i)$. Condition a) is satisfied by defining

$$\lim_{n \rightarrow \infty} m(n) = m. \quad (156)$$

Thus the sum of these independent bernoulli trials converges to a poisson distribution with equal mean. It is very important to note two very broad generalizations on the interpretation of the result. First, this result holds for pollution entering at any point in the estuary (various STP outfalls, a line source of land runoff, etc.). That this is true can be easily seen by recalling that individual units of BOD (or OD) are assumed to be independent of every other unit of BOD (or OD). This assumption would obviously extend to units of BOD discharged from different pollution sources. The probabilities of the total concentrations would be the convolutions of the concentrations due to the various sources. Since the distributions due to individual sources are poisson and the convolution of poissons is poisson with parameter equal to the sum of the individual parameters, the total concentration must be poisson distributed with parameter equal to the

total of the individual parameters or equivalently it is equal to the mean total concentration times Δ . Secondly, this result holds for any type of pollution which obeys the above assumptions of independence. This includes carbon and nitrogen forms of BOD, land runoff, benthal demand and any other components as long as their probability density functions are finite. Due to the relatively stable behavior of this natural process, it is unlikely that a probability density function would not be finite. A possible exception is the distribution of pollution at the instant of introduction to the estuary. The unit of BOD has not had time to be diffused. This should involve no difficulty for two reasons. First, the effect of the overall concentration by an individual BOD particle is negligible and the concentrations near STP outfalls are of less interest than the concentrations downstream at the dissolved oxygen sag point. This result we call the Poisson Approximation.

Recall that the pollution states were defined previously as the pollution concentration divided by Δ , the stochastic coefficient. Thus the mean concentration is equal to the product of the mean state and Δ . Similarly the concentration variance is the state variance times Δ^2 or the mean concentration times Δ . So, if the mean concentration is known, then the concentration variance can be calculated and since the distribution about the mean concentration is poisson, the entire concentration distribution is known

Recall that at the end of the previous section, it was pointed out that the differential equations (135) and (136) which were derived for probability density functions also have concentration interpretations. This fact together with the result just mentioned yields a great simplification to the convolution over the many pollution units involved and thus to the ultimate solution of the problem. If the equations (135) and (136) are allowed to take on

their concentration interpretation, they can be rewritten with the added term

$$\frac{\partial f}{\partial t} = E_f \frac{\partial^2 f}{\partial x^2} - U \frac{\partial f}{\partial x} + R_f \quad (157)$$

and

$$\frac{\partial g}{\partial t} = E_g \frac{\partial^2 g}{\partial x^2} - U \frac{\partial g}{\partial x} + R_g \quad (158)$$

where

- $R_f (R_g)$ is the net rate of increase in BOD (OD) at (x, t) due to all sources and sinks, this includes $K_d f$, L_R , FF , etc. for BOD and $K_2 g$, $K_1 f$, D_b , photosynthesis, etc. for OD
- $K_d f$ is the rate of decrease in BOD due to oxygen and non-oxygen consuming processes
- L_R is the rate of increase in BOD due to land runoff
- FF is the rate of increase in BOD due to STP outputs
- $K_2 g$ is the rate of decrease in OD due to reaeration
- $K_1 f$ is the rate of increase in OD due to oxidation
- PS is the rate of decrease in OD due to photosynthesis
- D_b is the rate of increase in OD due to benthic demand. Normally PS will be included in this term.

Thus, the solution of equations (157) and (158) for concentration, carried out so that the source and sink terms are incorporated into the solution, automatically convolutes the individual BOD and OD units. This one solution together with the stochastic coefficient Δ yields the complete probability density function for all points in the tidal cycle for every position in the estuary. Once the concentration is determined, it is multiplied by Δ to get the poisson variance about the mean and the complete distribution is then known.

SOLUTION OF THE DIFFERENTIAL EQUATIONS FOR THE MEAN

Equations (157) and (158) rewritten in a computational form are given by

$$\frac{\partial f(x,t)}{\partial t} = E_f(x,t) \frac{\partial^2 f}{\partial x^2} - U(x,t) \frac{\partial f}{\partial x} - K_d(x,t)f + L_R(x,t) + FF(x,t) \quad (159)$$

and

$$\frac{\partial g(x,t)}{\partial t} = E_g(x,t) \frac{\partial^2 g}{\partial x^2} - U(x,t) \frac{\partial g}{\partial x} - K_2(x,t)g + K_1(x,t)f + D_B(x,t) \quad (160)$$

These equations can not be solved analytically, therefore, a computer program was written to solve them numerically. All the terms on the right hand side of (159) and (160) can be evaluated so that $\partial f/\partial t$ and $\partial g/\partial t$ can be determined. The differentials are evaluated with sixth order difference equations and the coefficients, sources and sinks are determined for the estuary in question and fed into the program as input data. With values of $\partial f/\partial t$ and $\partial g/\partial t$ the solutions are integrated through time using the Runge-Kutta-Mersen method. A program listing (simulation program) is given in the appendix.

The section of the estuary which is of interest is divided into "finite thickness" cross sectional sheets. The sheet thickness used in the OD solution may be some integer multiple of the BOD solution sheet thickness.

The BOD concentration profile would be expected to be more sharply peaked than the OD profile since vast quantities of pollution are being introduced into the BOD process by "point sources" while OD is being created due to line sources which are spread over the entire estuary section. The center of each sheet is called a grid point. Point values for each of the parameters, feeds, etc. are assigned for each grid point.

That is, the continuous process is discretized. Then the sheet thicknesses are reduced in repeated computer runs until further reduction in grid spacings (sheet thickness) has no effect on the predicted concentration profiles. Thus, a continuous limit is taken of the discretized process. Due to the way the pollution input must be handled, it may not be practical to require a complete convergence near the major pollution source. This will be discussed further at the end of this section.

DATA REQUIREMENTS.

Listed below are those parameters, etc. for which information is required.

1. NG and NF The smallest number of sheets which can be used in the OD and BOD solutions and still get convergent solutions. NF can be any integer multiple of NG provided both solutions converge. The numbers are increased until further increases have no effect on predicted profiles.

2. XI and XO. The upper and lower boundaries in miles from some convenient upstream landmark. The fresh water flow is from XI toward XO. XO must be greater than XI. XI is usually set at or above the upper limit of tidal action. XO is set beyond our field of interest and in an area in which concentrations are not changing wildly through the tidal cycle.

3. TI and TM. Beginning and ending values in "real time" hours of the solution. TI must correspond to the initial values given for the G and F profiles. TM is set at a value greater than the value needed to reach pseudo-steady state. TM is determined by making several computer runs at different values of TM.

4. PRI. Number of real time hours between printing of predicted profiles.

5. OMEGA. Tidal frequency. $2\pi/\omega$, (0.507 for the Potomac Estuary and 0.0 for the Ohio River).

6. OMEGAF. Frequency of sinusoidal variation in feed rate $2\pi/24 = 0.262$ if variation is over a 24 hour

period. The program can be easily modified to handle any reasonable functional form to describe the feed input from STP as a function of time.

7. NS and XS(i), $i=1, 2, \dots, NS$. The number of places and their corresponding positions in miles at which output is required. Thus, after every print interval is completed, predicted concentrations are given at each position XS(i), $i=1, 2, \dots, NS$. The concentration profiles are determined from these values. The XS values (positions) should be selected to give maximum information. That is, more should be placed in area in which concentrations vary considerably and fewer in areas of stable concentrations.

8. G and F. Initial values of the G and F profiles corresponding to the initial time, TI. Generally both G and F are initially set equal to zero throughout the estuary.

9. UF and UT. Fresh water and tidal components of velocity. The following functional form was used for $U(x,t)$ in equations (159) and (160)

$$U(x,t) = UF(x) + UT(x) \cdot \sin(\omega t) \quad (161)$$

where

$U(x,t)$ is the average cross sectional fluid velocity

$UF(x)$ is the average cross sectional fresh water velocity as a function of position

$UT(x)$ is the average cross sectional value of maximum tidal velocity as a function of position or

is the average cross sectional tidal velocity at rush tide

ω is OMEGA in 5. above.

UF is calculated from the fresh water flow rate and channel geometry.

UT can be measured or can be approximated from the lower boundary tidal elevation function, channel geometry, and hydrodynamic relationships

10. EG and EF. Diffusion coefficients for OD and BOD respectively. Both can be functions of position.

11. K_1 . Reaction rate constant for biological utilization of BOD as a function of position.

12. K_4 . Rate constant for decrease of BOD by oxygen

and non-oxygen consuming process as a function of position.

13. K_2 . Reaeration rate constant as function of position.

14. D_b and L_R . Rate of increase in OD and BOD concentrations due to benthic demand and land runoff, respectively. Both can be functions of position. PS must be included in D_b .

15. FF. Rate of increase of BOD concentration due to STP outputs. The amounts of first and second stage UOD for each STP with the STP positions must be available.

16. Upstream boundary conditions. Measured concentrations if possible arbitrary but reasonable values if necessary for both F and G.

Note that K_2 is a function of turbulence, among other factors. Thus, if an estuary is being simulated, K_2 must be adjusted for tidal velocity. The function used in this work for the adjustment is

$$K_2(x,t) = C \cdot K_2(x) \cdot |\sin(\omega t)| \quad (162)$$

where

C is a proportionality factor so that the average value of $K_2(x,t)$ over a full tidal period will equal $K_2(x)$.

C is evaluated by setting

$$\frac{C}{12.4} \int_0^{12.4} K_2(x) |\sin(\omega t)| dt = K_2(x) \quad (163)$$

which yields

$$C = \frac{12.4\omega}{4} = \frac{12.4 \cdot 2\pi}{4 \cdot 12.4} = \frac{\pi}{2} = 1.5708.$$

If simulating a river, no correction to $K_2(x)$ is needed.

Of the parameters given above, different parameters are estimated with vastly different degrees of accuracy. For example K_1 , UF, and FF can probably be estimated with $\pm 10\%$ without much difficulty. While estimates for D_b , L_R , E_g , and E_f are often considered good if

they are within 50% of their true values. Thus, it was recognized that attempting to find L_R , for example, as a function of position would be completely point-less and that an average value for the entire estuary section should be used. But at the same time, some parameters could be measured or estimated with a degree of accuracy that would reasonably permit them to be considered as functions of position. That is, estimates may be available for some but not all the parameters as functions of position. For these reasons several different parameter categories will be given here, the use of these will be discussed in the PROGRAM DOCUMENTATION section. This is done to reflect the degree of information available on the individual parameters. Also, the different categories are handled differently as input data. The categories are the following:

- A. The parameter is constant throughout the estuary section of interest.
- B. The parameter is constant within a segment, having different values in different segments.
- C. The parameter is a smooth function of position, several pairs of values for position and parameter value at the position are available for curve fitting.
- D. Values are used only at certain grid points. This is primarily for FF input.

Items 1 through 15 in the above list are supplied to the program in the form of data. Item 16 and the correction to $K_2(x)$ must be included inside the program. How this is done is explained in the documentation section along with several actual examples.

The process parameters, E_s , E_f , K_1 , K_2 , K_4 , etc. are used in the simulation as point values at the grid points. Benthic demand, land runoff, and STP outputs are not incorporated so easily. Each of these terms in equations (159) and (160) have the units lbs/hr/vol, but are usually available only in units of lbs/hr in the case of STP output or lbs/hr/segment in the cases of land runoff and benthic demand.

Land runoff and benthal demand are handled in the following way:

1. Divide lbs/hr/segment values by the corresponding vol/segment values.

2. Use the resulting lbs/hr/vol as input to the program as the units are now correct. Since land runoff and benthal demand are introduced all along the estuary (line source), a value for each should be defined at each grid point.

STP outputs are handled in the following way:

1. Divide the lbs/hr values by the cross sectional area at the STP outfall. Care should be used to get an accurate value for cross sectional area, as the solution is quite sensitive to it.

2. Use these lbs/hr/area values as input to the program. Since the STP outputs are point sources, they will have non-zero values only at specific grid points.

3. The program divides the lbs/hr area by the "differential sheet" thickness converting to units of lbs/hr/vol.

Thus land runoff and benthal demand would be classified in either catagory A, B, or C, while STP output would be classified in catagory D.

Notice that as the grid spacing approaches zero the STP output approaches the function

$$\lim_{\Delta x \rightarrow 0} FF(x_0) (u(x_0) - u(x_0 + \Delta x)) / \Delta x = FF \delta(x_0) \quad (164)$$

where

$u(x)$ is the unit step function

FF is the STP output rate

$\delta(x)$ is the dirac delta function or unit inpulse.

The dirac delta can be defined in either of the following ways:

$$\delta(x_0) = \lim_{\Delta x \rightarrow 0} Z \quad (165)$$

where Z is a constant function with value $1/\Delta x$ and width Δx centered around x_0 or alternatively

STP plant $\delta(x) = 0$ for all $x \neq x_0 = \text{location of}$

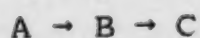
and
$$\int_{-\infty}^{\infty} \delta(x) dx = 1.0. \quad (166)$$

Thus $FF\delta(x_0)$ approaches infinity as the grid spacing approaches zero. This is the reason that complete convergence near the STP outfall may not be practical.

DISCUSSION OF MODEL

At this point a model has been developed and the information needed to use it has been itemized. In this section a discussion will be given of what this model will and will not do.

Basically the model describes an irreversible series chemical (biochemical) reaction of the type.



or



where C is of no interest. The reaction takes place in a one dimensional flow process in which mass transfer by bulk flow and diffusion is permitted. Also in this flow process are several point sources of BOD (STP) and line sources for BOD and OD (land runoff and benthic demand).

From basic chemical reaction kinetics it is seen that concentration profiles similar to those in Figure 8 would be expected.

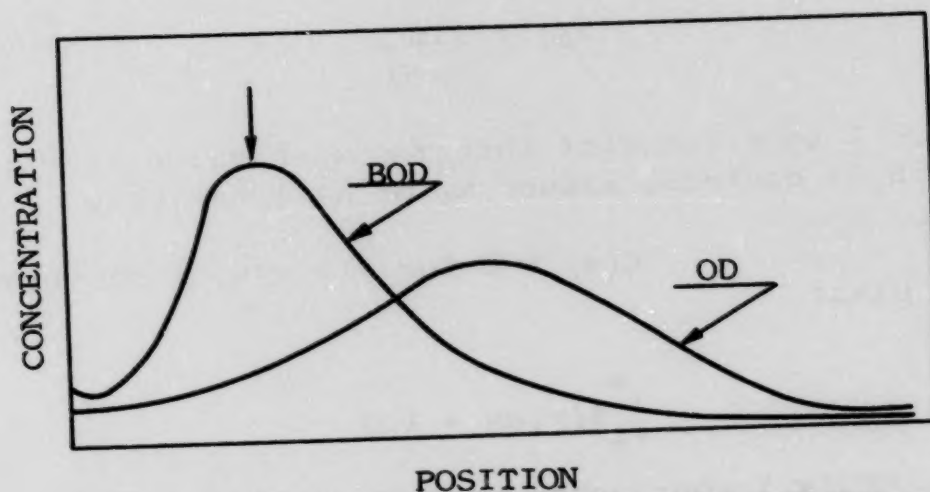


FIGURE 8 BOD AND OD PROFILES IN AN ESTUARY

The arrow indicates the location of the BOD input. The BOD concentration decreases moving away from the STP location in both directions, due to both biological utilization and bulk flow above the plant and utilization below the plant. Below the plant, the concentration decreases to a value a little greater than zero. This non-zero value, far from the source, is the result of the BOD line source, land runoff. The OD profile is smoother than the BOD profile and displaced downstream from it. The concentration increases with position until a point is reached at which the rate of creation of OD from benthic demand and biological utilization of BOD just equals the rate of absorption of OD by reaeration. Beyond this point OD decreases until it reaches a small non-zero value, which results from the creation of OD from the small amount of BOD remaining and from benthic demand.

An interesting special case of this occurs if the diffusion coefficients are set equal to zero. The model then simplifies to a variable coefficient and variable feed version of Dobbin's model. In such a case concentration profiles similar to those in Figure 9 would

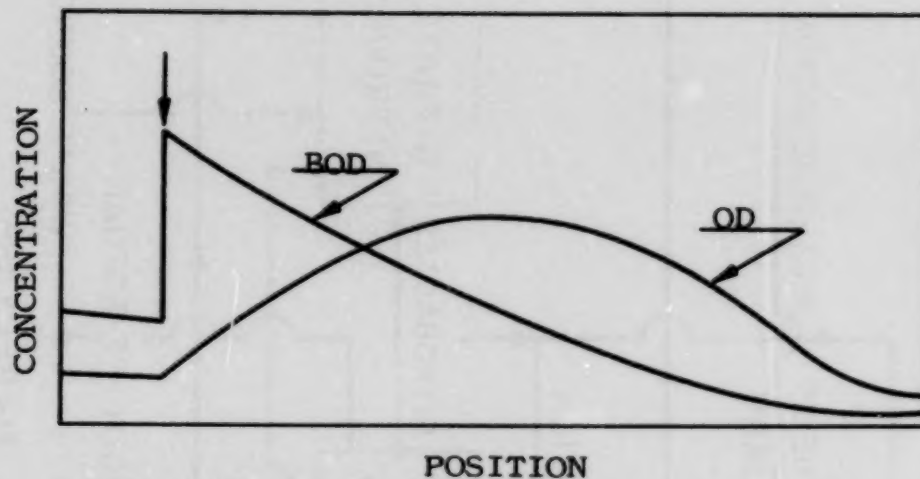
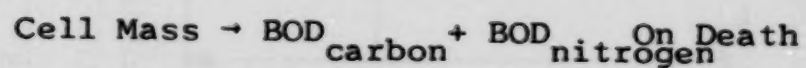
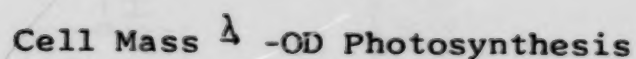
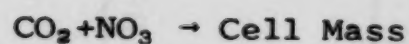
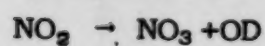
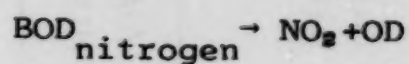
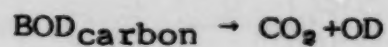


FIGURE 9 BOD AND OD PROFILES IN A RIVER

be expected.

Several recent studies, Jaworski [40], Thomann, O'Connor, and Di Toro [76], have indicated that pollution in estuaries follows a more complex reaction pathway than the simple series reaction discussed above. A brief outline of the pathways is given here



where C is a component which is not of interest and λ signifies sunlight. See Figure 10 for a schematic

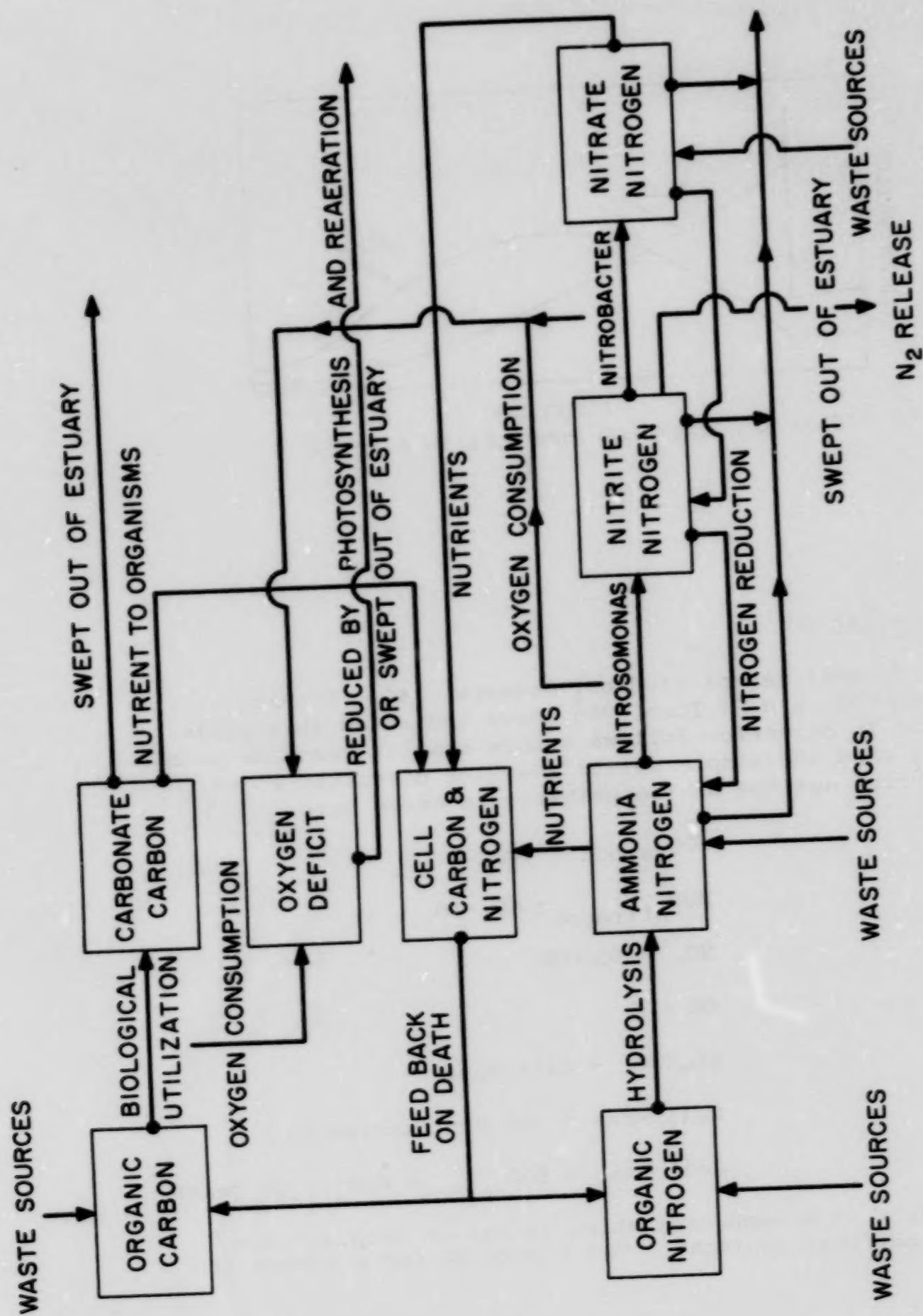


FIG. 10 SCHEMATIC DIAGRAM OF PARALLEL - SERIES REACTION WITH NITROGEN AND CARBON RECYCLE

diagram of parallel-series reaction with nitrogen and carbon recycle.

In this reaction pathway nitrogen and carbon pollutants and the creation of dissolved oxygen by photosynthesis must be considered separately, and an accounting for the recycling of carbon and nitrogen through organic forms must be performed. Obviously, the simple model obtained in this project can not accurately describe the behavior of BOD in an estuary in which the above three (and other) processes are important. See the RECOMMENDATIONS for further discussion.

The concentration profiles expected with a parallel series reaction of this type as compared with the simple series reaction would be similar to those in Figure 11.

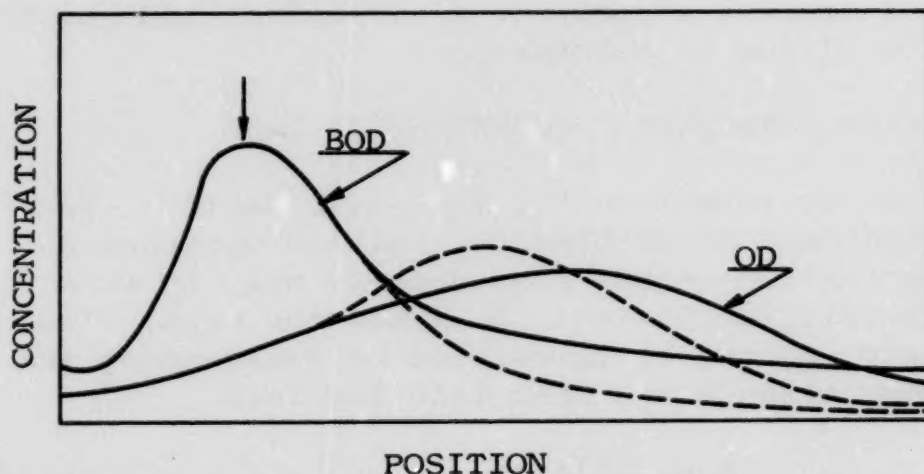


FIGURE 11 COMPARISON OF BOD AND OD PROFILES WHICH WOULD BE EXPECTED WITH THE SIMPLE-SERIES AND PARALLEL-SERIES

BOD, which is the sum of the carbon and nitrogen pollutants, would stay at a higher level downstream due to recycling of these components through organic forms. OD would be less peaked due to the effect of

photosynthesis, but would have a high concentration further downstream due to the contribution of the recycled nitrogen and carbon components.

Another limitation on this and any other reaction rate model of its type is that the BOD processes have been assumed to be independent of the OD level. This is probably a good assumption for relatively high DO levels. Field work seems to indicate that the assumption fails for DO concentrations below 1 ppm. Thus, this model must be restricted to estuaries in which the DO level does not frequently fall below 1 ppm.

STOCHASTIC COMPONENT OF THE MODEL

It has been shown previously that once the mean concentration of pollutant has been found, the probability distribution about this mean can be found by superimposing the stochastic component, a scaled and translated poisson distribution, over the mean. This scaled and translated poisson distribution and how it is found will now be discussed.

SCALE FACTOR, STOCHASTIC COEFFICIENT, OR Δ

First to be considered is the scale factor. Recall that it has been shown that the poisson variance of the concentration values around their mean is equal to the stochastic coefficient, Δ , times the mean. The coefficient, Δ , can be calculated by rearranging the expression $\text{variance} = \Delta \cdot \text{mean}$ into the form

$$\Delta = \frac{\text{Variance}}{\text{Mean}} \quad (168)$$

Then by using observed data from the estuary in question to get means and variances, Δ can be found. Care must be used in calculating these values, however, to avoid distortion. The data used in calculating a mean and the corresponding variance must have the same true mean. Thus if a large amount of data were taken over some time interval at a certain point in an estuary, care

must be used to remove any deterministic diurnal variations due to photosynthesis and tidal excursion. From this point on, the discussion of Δ will carry through, as an example, data which was taken by WQO in the summer of 1967.

DO and water temperature measurements were taken every half hour for 30 days at one sampling station and for 14 days in three others. The four stations covered the upper 30 miles of the Potomac estuary.

To check for time of day variation, twenty-four hourly OD averages were calculated for each of the four sampling stations. Inspection of the means indicated a large variation with days due to photosynthesis, see Figure 12. Only the data which was taken between 5 and 9 am were used because during this time the data appeared uniform and the effect of photosynthesis would be minimized. Data which was taken within this time interval was then subdivided into 12 groups according to tidal phase to remove tidal effects. Means, variances, and Δ values, were calculated for each tidal phase subgroup and an overall average Δ was calculated for each station. These calculations were done by a computer program (Δ program) which is given in the appendix. Different programs were needed for estuaries and rivers. A Δ program was written for each case and listed in the appendix.

The estuary Δ program works in the following way.

1. A header card is read which indicates the sampling station number, number of samples taken at this station and the time of high tide on a specified day.
2. Data cards are read one at a time, one DO value for each card. The number of cards read corresponds to the number of samples given in the header card.
3. For each DO value the following operations are carried out.

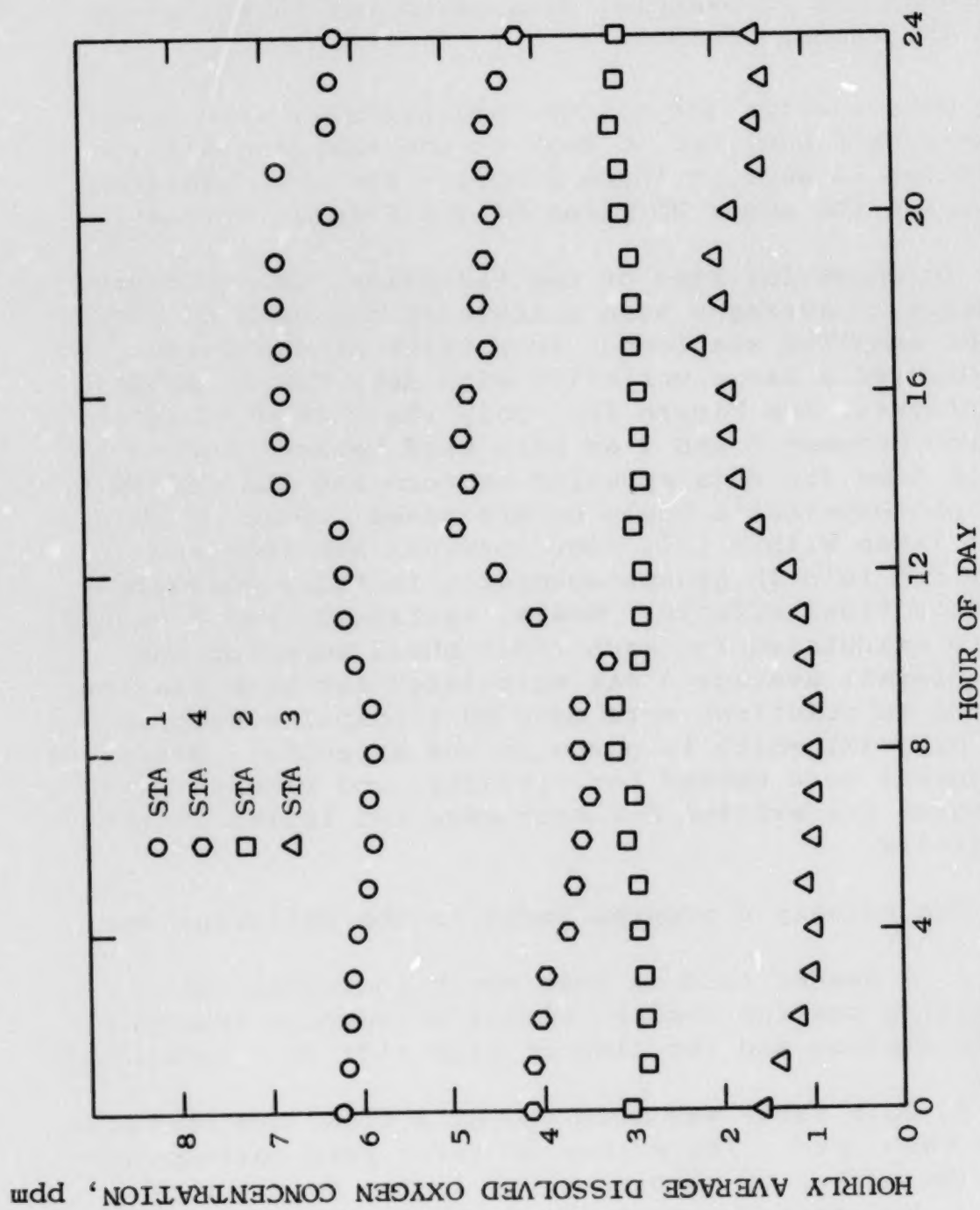


FIGURE 12 HOURLY AVERAGE OF DO CONCENTRATIONS AS FUNCTIONS OF TIME OF DAY FOR THE POTOMAC ESTUARY

A. Check for time of day. If outside of 5 to 9 am interval the data value is not considered. (This program can easily be changed to any appropriate time interval.)

B. If the DO sample was taken between 5 and 9 am, the DO value is converted to OD

C. The tide phase corresponding to the time and day the value was taken is calculated. Then the OD value is placed in one of the twelve subgroups according to phase value.

D. Within each subgroup sums of OD and sums of OD values squared are accumulated.

Steps A through D are repeated for each card read in step 2. Step 2 is repeated for all the data specified in Step 1.

4. Means and variance are calculated for each subgroup using the sums and sums of squares. Then Δ values for each subgroup and an overall average Δ is calculated for the station.

Steps 1 through 4 are repeated for each additional station.

The Δ values calculated for each of the four stations are given in Table 3.

Table 3. Δ values for the Potomac by station

Station 1	Station 2	Station 3	Station 4
0.226	0.260	0.0254	0.2022

The values for stations 1, 2 and 4 are in reasonable agreement. The station 3 value is certainly out of range. This is an important result and will be discussed later. Inspection of the individual DO values for station 3 reveals that many are near 0 ppm and that the average is approximately 1.0 ppm. You will recall that 1.0 ppm DO has previously been set as the lower limit on the range over which this model can be used.

The relatively close agreement of Δ values from station 1, 2, and 4 does not imply that Δ is a constant

through out the estuary. It is entirely possible that Δ could be a function of several estuary characteristics, conditions, etc. The functional form and estimation procedures for Δ will be discussed in another section of this report.

THE COMPLETE STOCHASTIC MODEL

A method is now available to calculate the scaling factor for the poisson probability distribution around the mean. Next to be discussed is the addition of the stochastic component to the deterministic mean. This stochastic component could be added by repeatedly taking random values from the poisson distribution and adding them to the deterministic mean. This would be a stochastic model in the Monte-Carlo or Stochastic Simulation sense. However, this is usually done when the type of probability distribution and the value of its parameters are not known and the simulation is done to help determine them. This is not the case here. Thus, the generation of thousands and thousands of random stochastic components using the known distribution is not necessary and will not be done. Another method of adding the stochastic component is to take the mean, determine the poisson variance and using a poisson distribution calculate confidence limits about the mean.

This complete stochastic model, deterministic plus stochastic components, could be verified by making repeated comparisons between observed and predicted values and counting the number of times the observed values fall outside of the predicted confidence limits. If the 5% confidence limits are being considered, approximately 5% of the observed data would be expected to fall outside of the confidence limits. Since the model variance does not include the variance component due to lack of fit of the true mean concentration, nor the component due to random variation of the observed average about the true mean (sampling errors), a percentage of data outside confidence limits somewhat greater than 5% would not be unexpected. To account for these variance components, the Δ value may be adjusted.

To carry out this comparison, computer programs (analysis program, see appendix) were written which will carry out the following operations:

I. Read: 1. card output of simulation program, 2. the time at which high tide occurred on a specified day at each sample station, and 3. the positions in miles for the 16 points at which predicted means are given by the simulation program.

II. Subroutines are called which calculate concentration profiles through position in the estuary for fixed tidal phases of 0.0, 0.25, 0.50, and 0.75. Then profiles are calculated through the tidal cycle at each station of interest.

III. Now the verification portion of the program begins. A header card is read for each sampling station giving the number of data cards to follow for this station (1 BOD or DO value/card), the position in miles of the station, and the station number.

IV. Next data cards are read one at a time on which the month, day, and time of day at which the sample was taken and the observed BOD or DO sample value.

V. A check is made on sampling time. If the sample was not taken between 5 and 9 am the sample is disregarded and a new data card is read.

VI. If the sample was taken between 5 and 9 am, and DO is being considered, the DO value is converted to OD.

VII. A subroutine is called which calculated the tidal phase when the sample was taken using month, day, and time of part IV above. This subroutine is geared to the day for which the time of high tide was given in part I above.

VIII. Then, using the position in the estuary and the tidal phase when the sample was taken, a predicted mean concentration is determined by interpolating, if necessary, between the tidal phase and positions given by the simulation program.

IX. The poisson variance and $\alpha\%$ confidence limits about the predicted mean are calculated. Different values for α can be used.

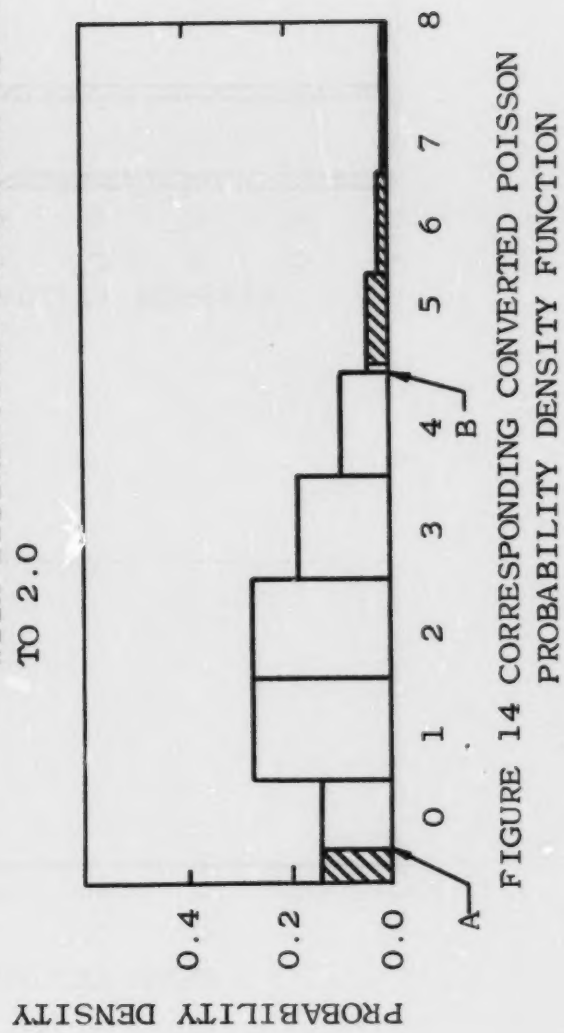
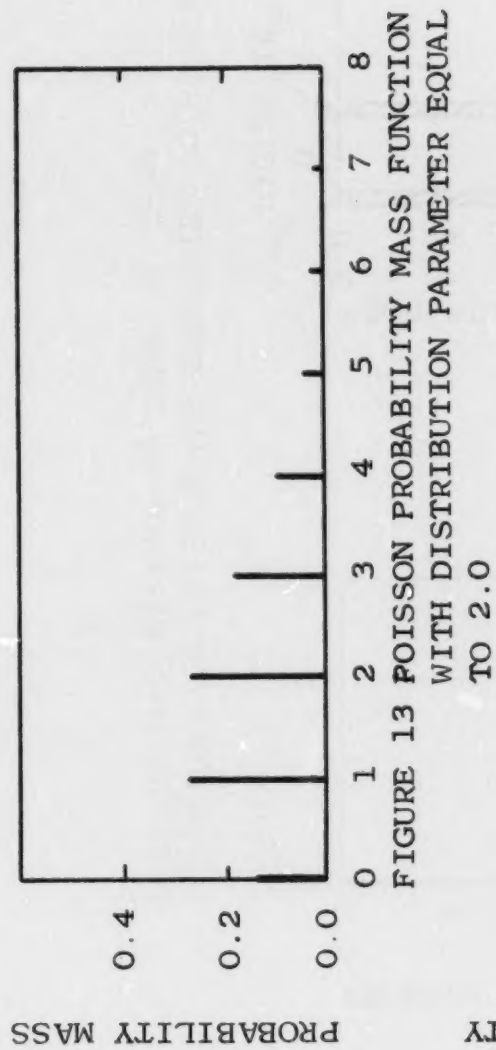
X. The observed value is compared to the confidence

interval limits. The number of values which do not fall inside the limits is tabulated and printed out after all the data for this station is read. Then steps III through X are repeated for each station of interest. In step VIII confidence intervals are calculated considering concentration as a continuous variable. Since the poisson is a discrete distribution, it was necessary to convert from a discrete to a continuous distribution. The method which was found most practical required that the poisson probabilities massed at the discrete values be spread uniformly over the interval from $\frac{1}{2}$ unit below to $\frac{1}{2}$ a unit above the respective integer values. Figures 13 and 14 illustrate how this is done. Once the conversion is made, the point which has $\alpha/2$ of the area under the curve to the left of it and the point with $\alpha/2$ area to the right of it are found. These two points represent the α level confidence limits. If $\alpha = 0.10$ the points A and B in Figure 14 would be those limits.

This method is quite accurate for moderate values of the poisson parameter, λ . But the method fails for very small λ values. This can easily be seen by considering the extreme case of $\lambda = 0.0$. In this case all the probability occurs at the zero value. Since in the poisson parameter λ is both the mean and the variance, the true confidence units must fall on zero. In the converted poisson this does not happen. The converted poisson minimum confidence interval length is $1-\alpha$. See Figures 15 and 16 for this comparison. Thus, for very small values of λ some correction of the converted poisson limits may be necessary.

The above program is primarily meant for use in the verification of the simulation program results. Another, possibly more useful, approach would require a program which would yield a summary of the probabilities of exceeding a given level of OD. Such a program has been written (see Limits Program in the appendix) and is used in the following way:

- I. Feed output of simulation program.
- II. Read card giving the position number where output



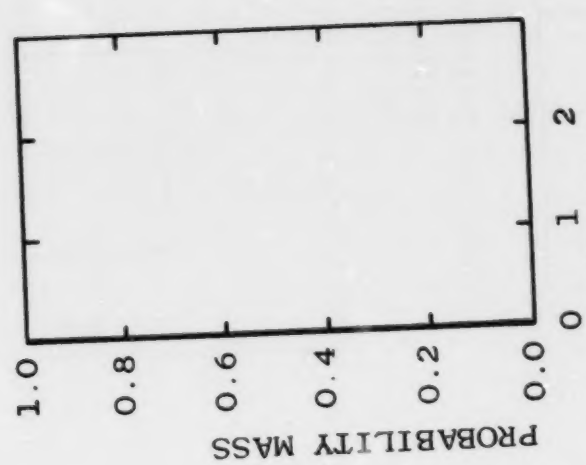
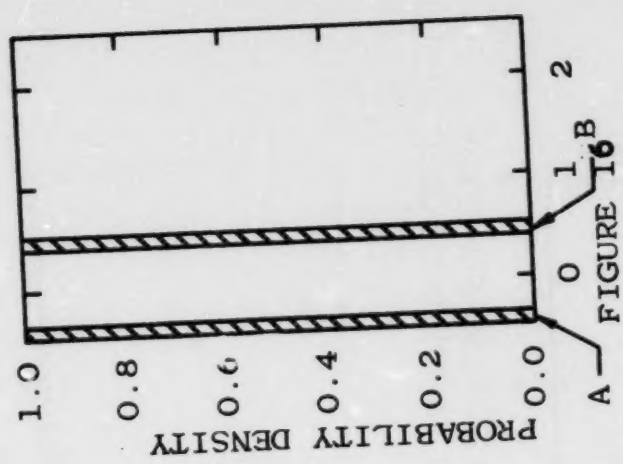


FIGURE 15
COMPARISON OF POISSON AND CONVERTED POISSON WITH
DISTRIBUTION PARAMETERS EQUAL TO ZERO

is required. The position number will range from 1 to 16 corresponding to the 16 position of I above.

III. For each card read in II a table of confidence limits is generated for each 0.01 increment in the tidal phase. The table is in the form given in Table 4.

Table 4. Table of alpha levels generated by the computer

PHASE	Alpha Level						
	0.05	0.10	0.15	0.20	0.25	0.30	0.40 0.45 etc.
0.00							
0.01							
0.02							
.							
.							
.							

Here the alpha level signifies the fraction of observations predicted to fall above the OD concentrations given in the table. Once familiar with the layout, the fraction of values predicted above a certain level can be determined at a glance. In addition a plot showing the 10%, 20%, 30%, 50%, 70%, 80%, and 90% limits is generated. At a glance the fraction of values predicted above a given OD concentration can be determined.

PROGRAM DOCUMENTATION

Given here is a detailed documentation of the simulation program. It is thought that the Δ programs and the analysis programs have sufficient documentation in the respective program listings (see the appendix) and in the previous discussion to permit their useage without further explanation.

A detailed list of inputs to the simulation program s given, with descriptions, in the DATA REQUIRMENT

subsection of the SOLUTION OF THE DIFFERENTIAL EQUATIONS FOR THE MEAN section. Most of the information needed for a simulation is fed to the program on data cards. Internal modifications are currently required to incorporate the upstream boundary conditions, the correction of $K_2(x)$ for variable fluid velocity, feed time variable functional forms, and a punched card output option.

INTERNAL MODIFICATIONS

Boundary conditions: Refer to simulation program in the appendix. Find the comment card "upstream boundary conditions" and carry out the directions given.

Correction factor for $K_2(x)$: Find comment card "correction factor for $K_2(x)$ ". In the card following the comments card, two options are available. The term XKSIN, the corrected $K_2(x)$ or $K_2(x,t)$, can be left if an estuary is being simulated or it can be replaced by $K2(I)$ if a river is being modeled.

Variable feed: If it is necessary to use a time varying feed, find comments card "variable feed". The variable "SFT" at this point is the fraction deviation of the current feed rate (STP output), $FF(t)$, from the long term average output, FF . The functional form used in this example is

$$FF(t) = FF + 0.001 FF \cdot \cos(\text{OMEGAF} \cdot t) \quad (169)$$

This is the functional form used in the Potomac verification. An essentially non-varying feed was used due to lack of information on $FF(t)$. Any other reasonable functional form can be substituted here as the need occurs.

Punched card output is possible: Find "punched card output option" comments cards. In the cards which follow these two comments cards, replace 400 with

"real time" hours at which punched output is desired. The time should be greater than the time necessary to reach steady state.

Data input: Since the formatting of FORTRAN IV is more stringent than that of PL/1, and this program is available in both languages (see the appendix), the explanation here will be for the FORTRAN IV program. The first data card must have the information listed in Table 5.

Table 5: Information required for first data card

<u>CARD</u>	<u>Column</u>	<u>Variable</u>	<u>Description</u>
1-5		NG	Number of grid spacings in estuary for OD.
6-10		NF	Number of grid spacings for BOD
11-20		XI	Upstream position. Upper boundary of estuary in miles.
21-30		XO	Downstream boundary.
31-40		TI	Time at beginning of simulation, usually 0.0.
41-50		TM	Time in hours at end of simulation.
51-60		PRI	Interval in real time hours between outputs.
61-70		OMEGA	Tidal frequency, $2\pi/\omega$ for estuaries, 0 for rivers.
71-80		OMEGAF	Frequency of sinusoidal feed rate.

AN EXAMPLE: The Potomac

60 120 0.0 20.0 0.0 500.0 1.0 0.5067 0.262

A listing of the actual data used is given in the appendix following the FORTRAN differential equation program.

The next set of information to be read is the number of points in the estuary that output is required of and the positions. This is given in Table 6.

Table 6: Information required for subsequent data cards.

<u>Card Column</u>	<u>Variable</u>	<u>Description</u>
1-5	NS	The number of positions
11-20	XS(1)	The 1st position in miles at which output is needed.
21-30	XS(2)	The 2nd position for output.
...		
71-80	XS(7)	The 7th position for output.
1-10	XS(8)	The 8th position for output.
...		
61-70	XS(14)	The 14th position for output.
1-10	XS(15)	The 15th position for output.

etc ... as many as required

EXAMPLE: The Potomac

```

16  0.0   3.0   4.8   6.0   8.0   9.0   10.0
11  0  11.0 13.0  14.0 15.0 16.0 17 0  20.0

```

The remaining estuary parameter variables can be classified into one of four categories, depending on the variable and the degree of accuracy with which it can be measured. The variables (and parameters) which fall in the same category are read in together as a group.

The following is a summary of the four categories.

<u>Catagory</u>	<u>Description</u>	<u>IPT</u>
A	The parameter is a constant throughout the estuary	-2
B	The parameter is constant within an estuary segment but may have different values in different segments	0
C	The parameter is a smooth function of position throughout the estuary and several pairs of values are available for the parameter at different positions. The number of pairs is equal to the IPT number.	>1
D	The variable takes on non-zero values only at certain positions. This is used only for point source, STP outputs.	-1

FOR the purpose of input, the various parameters must be given numerical identifications. The identifications used are summarized in the following:

<u>Variable</u>	<u>Description</u>	<u>Number, NV</u>
G	Initial OD concentration profile	1
F	Initial BOD concentration profile	2
UF	Fresh water velocity	3
UT	Tidal velocity	4
EG	OD diffusion coefficient	5
EF	BOD diffusion coefficient	6
K ₁	BOD utilization rate constant	7
K ₂	Reaeration constant	8
K ₄	Rate constant for decrease in BOD by oxygen and non-oxygen consuming processes	9
D _B	Benthal demand	10
L _R	Land runoff	11
FF	STP output	12

This data is read in the following way. The computer must first be told the data category, and the variable number about to be read. The next card (after the NS and XS cards which were discussed above) must have the appropriate values for IPT and NV. The category index, IPT, and variable number, NV, in card columns 1-5 and 6-10, respectively.

Example:

-2 1

This says the initial G profile (NV=1) will be read as a constant (IPT=-2).

Now that IPT and NV have been read, the next card must have the constant G value and the variable number to be read next.

Example:

0.0 2

The initial OD profile, G, is zero for the whole estuary and the value for initial BOD profile, F (NV=2), will be read next.

Cards like this, constant value for current variable and identification number for next variable, will be used until all the parameters in category "A" (IPT=-2) have been read. On the last card an NV value of zero should be used. A zero NV tells the machine to read a new IPT card. An example of how Category A might be done is given in Table 7.

Table 7: Information for IPT card.

<u>cc 5</u>	<u>cc 10</u>	<u>cc 15</u>	<u>Explanation</u>
-2	1		IPT = -2 (IPT card)
	0.0	2	$G(x,o) = 0.0$
	0.0	5	$F(x,o) = 0.0$
	0.1042	6	$EG(x) = 0.1042$
	0.1042	7	$EF(x) = 0.1042$
	0.020	9	$K_1(x) = 0.020$
	0.020	11	$K_d(x) = 0.020$
	20000	0	$L_R(x) = 20000$
			End of catagory A.

A new IPT card must be given for catagory B if there are any variables in this catagory. After IPT card, a card must be read which gives the downstream boundary of the first segment. This card is followed by a card which gives the value of the parameter in the first segment. Then a position card and a value card follow for the second segment, etc. for each segment. A position card with a negative position should follow the value for the last segment as in Table 8.

Table 8: Example of use of position card.

<u>cc 5</u>	<u>cc 10</u>	<u>Explanation</u>
0	5	IPT = 0 (parameter constant within a segment)
	5.0	
	0.08	EG = 0.08 from 0 to 5 miles
	10.0	
	0.10	= 0.10 from 5 to 10 miles
	15.0	
	0.12	= 0.12 from 10 to 15 miles
	20.0	
	0.10	= 0.10 from 15 to 20 miles
	-1.0	A position value $< 0 \leq XI$ means that EG has been complete.

These data cards could be followed by an NV card with NV = 0 (return for a new IPT card) or be a legitimate NV card and the whole process repeated for one or more other parameters which are in category B. An example with two parameters in category B is given in Table 9.

Table 9: Example with two parameters in Category D.

<u>cc 5</u>	<u>cc 10</u>	<u>Explanation</u>
0	5	IPT = 0
	10.0	
	0.10	EG = 0.10 from 0 to 10 miles
	20.0	
	0.12	= 0.12 from 10 to 20 miles
	-1.0	End of EG
6		
	10.0	
	0.10	EF = 0.10 from 0 to 10 miles
	20.0	
	0.13	= 0.13 from 10 to 20 miles
	-1.0	End of EF
0		End of Category B

Next a new IPT card is read for category C. The IPT value gives the number of pairs of values which will be given for variable beings considered. The pairs of values will be in this order; position 1 and value of parameter at position 1, position 2 and value at position 2, position 3 and value at position 3, etc. see Table 10.

Table 10: Example (variable NV=8, 5 pairs of values).

<u>cc5</u>	<u>cc10</u>	<u>cc20</u>	<u>cc30</u>	<u>cc40</u>	<u>cc50</u>	<u>cc60</u>	<u>cc70</u>	<u>cc80</u>
5	8							
	0.673	0.00208	2.02	0.00208	3.212	0.00375	4.255	0.00375
	5.217	0.00708						

Several variables in category C would be handled in the way depicted in Table 11.

Table 11: Example with several variables in Category C.

5	8								
	0.673	0.00208	2.02	0.00208	3.212	0.00375	4.255	0.00375	
	5.217	0.00708							
0									
6	4								
	0.0	0.0	12.3	0.3863	3.735	0.4421	5.655	C.4812	
	7.185	0.568	8.775	0.805					
0									

Notice that after each variable in category C the return for a new IPT card is given. This is not absolutely necessary if two successive parameters in category C have the same number of pairs. A real NV could be used.

Category D, FF, would be handled in the following way. Read an IPT card given in Table 12.

Table 12: IPT card.

<u>cc 5</u>	<u>cc 10</u>
-1	12

Follow this by a card with the position of the uppermost STP plant. This is followed by the rate of pollution input by this plant in units of lbs/hr/square mile. Position and input rate cards should follow for each STP plant in the estuary under consideration. After the last rate card insert a card with -1 in cc 4 and 5. If the position of an STP is outside of the interval XI to XO it is not included as data here, but must be included elsewhere. Either in the upstream boundary

conditions if upstream of XI or, if it is downstream,
either neglect it or extend XO to include the STP.
See Table 13.

Table 13: Example for FF.

<u>cc 5</u>	<u>cc 10</u>
-1	12
	9.0
	1.5E+06
	10.0
	1.12E+07
	12.2
	0.728E+06
	19.6
	etc.
-1	
-1	

The second -1 tells the machine that all the data has
been read.

The input for the PL/1 program is exactly the same
as this except that it is "Free Format Input". The
above example for FF would be given by Table 14 in
PL/1.

Table 14: FF in PL/1

-1	12	9.0	1.5E+06	10.0	1.12E+07	12.2	0.728E+06	19.6	0.37E+05
22.0	0.18E+05	-1	1.						

A GENERAL PARTIAL DIFFERENTIAL EQUATION DESCRIBING THE BEHAVIOR OF ANY SOLUBLE POLLUTION COMPONENT IN AN ESTUARY

Here we derive an extension to the present stochastic model which can be used for any soluble pollution component in an estuary. It is this extension which can be used to solve the algae problem.

Previously it has been shown that to stochastically model pollution concentrations in an estuary, it is necessary only to determine the mean concentration. Once the deterministic mean is known the probability distribution about the mean is found by superimposing a translated and scaled poisson distribution onto the mean. The degree of scaling is determined by the stochastic coefficient, Δ , which is determined from the observed OD and BOD data from the estuary in question. The scaled poisson is then translated until its mean coincides with the deterministic mean mentioned above. Thus the difficulty is in determining the mean concentration as a function of position and time. This is a difficult problem in that many, as yet not fully understood, processes must be incorporated into the model. Some of the more important processes include:

1. Estuary Hydraulics
2. Photosynthesis
3. Nitrogen and Carbon Recycle Through Organic Forms
4. NH_3 - NO_2 - NO_3 series reaction.

The first step in this overall problem is the derivation of a general partial differential equation with which the behavior of any soluble pollutant can be described. If this step is done properly, the physical processes (hydraulic and diffusion processes) will immediately be incorporated into the model and the chemical, biochemical, and biological processes can easily be added to the extent to which they are understood. In this section such an equation is derived.

Consider a cross-sectional sheet in an estuary such as given in Figure 17.

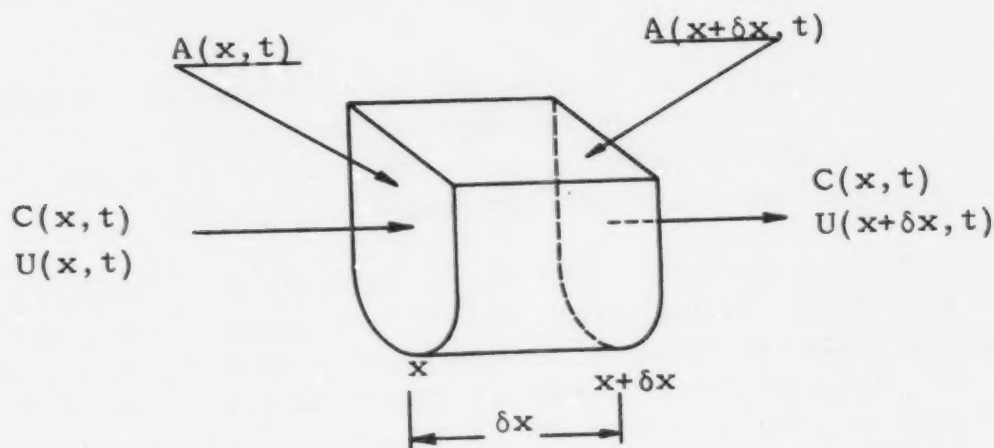


FIGURE 17 DIFFERENTIAL CROSS SECTIONAL SEGMENT OF AN ESTUARY

with all concentrations, parameters, estuary characteristics, feeds, etc. being functions of time (not just tidal phase) and position.

Using the general law of conservation of mass on a particular but unspecified pollution component,

$$\text{Input} - \text{Output} = \text{Accumulation} - \text{Generation} + \text{Depletion.} \quad (170)$$

Input: The rate of mass input at x and t is

$$I(x, t) = [U(x, t)A(x, t)C(x, t) - E(x, t)A(x, t)\partial C(x, t)/\partial x] \quad (171)$$

$I(x, t)$ is the rate of mass input at x and t . The rate of mass input at x and $t + \delta t$ is

$$I(x, t + \delta t) = I(x, t) + (\partial I(x, t)/\partial t)\delta t \quad (172)$$

Using a truncated Taylor's series, the average mass input at x over the interval t to $t + \delta t$ is

$$[I(x, t) + \frac{1}{2}(\partial I(x, t)/\partial t) \delta t] \delta t = I(x, t) \delta t + \frac{1}{2}[\partial I(x, t)/\partial t](\delta t)^2 \quad (173)$$

Output: The rate of mass output at $x+\delta x$ and t is

$$O(x+\delta x, t) = [I(x, t) + (\partial I(x, t)/\partial x) \delta x]. \quad (174)$$

The rate of mass output at $x+\delta x$ and $t+\delta t$ is

$$O(x+\delta x, t+\delta t) = O(x+\delta x, t) + [\partial O(x+\delta x, t)/\partial t] \delta t. \quad (175)$$

The average mass output at $x+\delta x$ over the interval t to $t+\delta t$ is

$$\begin{aligned} & [O(x+\delta x, t) + \frac{1}{2}(\partial O(x+\delta x, t)/\partial t) \delta t] \delta t \\ \text{or} & [I(x, t) + (\partial I(x, t)/\partial x) \delta x + \frac{1}{2}[(\partial I(x, t)/\partial t) \delta t + (\partial^2 I(x, t)/\partial x \partial t) \delta x \delta t]] \delta t \end{aligned}$$

or

$$I(x, t) \delta t + (\partial I(x, t)/\partial x) \delta x + \frac{1}{2}(\partial I(x, t)/\partial t) \delta t^2 + \frac{1}{2}(\partial^2 I(x, t)/\partial x \partial t) \delta x \delta t^2 \quad (176)$$

Input-Output: The difference input-output can be expressed as the difference in equations (173) and (176)

$$\begin{aligned} & I(x, t) \delta t + \frac{1}{2}(\partial I(x, t)/\partial t) \delta t^2 - I(x, t) \delta t \\ & - (\partial I(x, t)/\partial x) \delta x \delta t - (\partial I(x, t)/\partial t) \delta t^2 - \frac{1}{2}(\partial^2 I(x, t)/\partial x \partial t) \delta x \delta t^2 \end{aligned} \quad (177)$$

Cancelling terms, neglecting all terms of $o(\delta x^2)$ and dividing by $\delta x \delta t$ yields:

$$\text{Input-Output} = -(\partial I(x, t)/\partial x) \quad (178)$$

where

$$I(x, t) = [U(x, t)A(x, t)C(x, t)]$$

$$- E(x,t)A(x,t) \partial C(x,t) / \partial x]. \quad (179)$$

Then

$$\begin{aligned} \text{Input-Output} = & -AC \frac{\partial U}{\partial x} - UC \frac{\partial A}{\partial x} - UA \frac{\partial C}{\partial x} + A \frac{\partial E}{\partial x} \frac{\partial C}{\partial x} \\ & + E \frac{\partial A}{\partial x} \frac{\partial C}{\partial x} + EA \frac{\partial^2 C}{\partial x^2}. \end{aligned} \quad (180)$$

Accumulation: The average mass content of the section, x to $x+\delta x$, at time t is

$$\begin{aligned} & [C(x,t) + \frac{1}{2}(\partial C(x,t) / \partial x) \delta x] [A(x,t) \\ & + \frac{1}{2}(\partial A(x,t) / \partial x) \delta x] \delta x. \end{aligned} \quad (181)$$

For convenience let

$$\begin{aligned} & [C(x,t) + \frac{1}{2}(\partial C(x,t) / \partial x) \delta x] = M(x,t) \\ \text{and} \quad & [A(x,t) + \frac{1}{2}(\partial A(x,t) / \partial x) \delta x] = N(x,t). \end{aligned} \quad (183)$$

The mass content at time $t+\delta t$ is then

$$\begin{aligned} & [M(x,t) + (\partial M(x,t) / \partial t) \delta t] [N(x,t) \\ & + (\partial N(x,t) / \partial t) \delta t] \delta x. \end{aligned} \quad (184)$$

Then using the expression

$$\begin{aligned} \text{Accumulation} = & \text{Mass at time } t+\delta t - \text{Mass} \\ \text{at time } t & = [M(x,t)N(x,t) + (\partial M(x,t) / \partial t) \\ & \cdot N(x,t) \delta t + M(x,t) (\partial N(x,t) / \partial t) \delta t + (\partial M(x,t) / \partial t) (\partial N(x,t) / \partial t) \delta t^2 \\ & - M(x,t)N(x,t)] \delta x. \end{aligned} \quad (185)$$

Cancelling terms, neglecting all terms of $o(\delta x^2)$, and dividing by $\delta x \delta t$ yields

$$\begin{aligned} \text{Accumulation} = & (\partial M(x,t) / \partial t) N(x,t) \\ & + M(x,t) (\partial N(x,t) / \partial t). \end{aligned} \quad (186)$$

Recalling the definition of $M(x,t)$ and $N(x,t)$ gives

$$\begin{aligned} \text{Accumulations} = & \left(\frac{\partial C(x,t)}{\partial t} + \frac{1}{2} \frac{\partial^2 C(x,t)}{\partial x \partial t} \cdot \delta x \right) A(x,t) \\ & + \frac{1}{2} \frac{\partial A(x,t)}{\partial x} \delta x \left(C(x,t) + \frac{1}{2} \frac{\partial C(x,t)}{\partial x} \delta x \right) \left(\frac{\partial A(x,t)}{\partial t} + \frac{1}{2} \frac{\partial^2 A(x,t)}{\partial x \partial t} \delta x \right) . \end{aligned} \quad (187)$$

Taking the limit as δx and δt approach zero

$$\begin{aligned} \text{Accumulation} = & A(x,t) \frac{\partial C(x,t)}{\partial t} \\ & + C(x,t) \frac{\partial A(x,t)}{\partial t} . \end{aligned} \quad (188)$$

Generation and Depletion: All generation and depletion terms will be considered together. The net effect of all source and sink terms will be considered as a net source term. Let $R(x,t)$ be the net rate of increase in $C(x,t)$ due to all source and sink terms.

The average rate of increase of concentration over the section with volume $(A(x,t) + \frac{1}{2}(\partial A(x,t)/\partial x) \delta x) \delta x$ can be expressed at time t as

$$P(x,t) = [R(x,t) + \frac{1}{2}(\partial R(x,t)/\partial x) \delta x] . \quad (189)$$

The average rate of increase in concentration over the section at time $t + \delta t$ can be expressed

$$P(x,t) + \frac{1}{2}(\partial P(x,t)/\partial t) \delta t . \quad (190)$$

Then the average rate of increase in concentration in the section over the time interval t to $t + \delta t$ is

$$\begin{aligned} & P(x,t) + \frac{1}{2}(\partial P(x,t)/\partial t) \delta t = R(x,t) \\ & + \frac{1}{2}(\partial R(x,t)/\partial x) \delta x + \frac{1}{2}(\partial R(x,t)/\partial t) \delta t + \frac{1}{4}(\partial^2 R(x,t)/\partial x \partial t) \delta x \delta t . \end{aligned} \quad (191)$$

Multiplying out, dividing by $\delta x \delta t$, and taking the limit as δt and $\delta x \rightarrow 0$ yields

$$\text{Generation} - \text{Depletion} = A(x,t)R(x,t) \quad (192)$$

Grouping all the expressions derived above, equations (173), (176), (188), and (192) according to the general law of conservation of mass yields

$$\text{Input-Output} = \text{Accumulation}$$

$$- \text{Generation} + \text{Depletion}$$

$$-AC \frac{\partial U}{\partial x} - UC \frac{\partial A}{\partial x} - UA \frac{\partial C}{\partial x} + A \frac{\partial E \partial C}{\partial x \partial x} + E \frac{\partial A \partial C}{\partial x \partial x} + EA \frac{\partial^2 C}{\partial x^2} =$$

$$A \frac{\partial C}{\partial t} + C \frac{\partial A}{\partial t} - RA \quad (193)$$

Rearranging and dividing by $A(x,t)$ gives

$$\frac{\partial C}{\partial t} = E \frac{\partial^2 C}{\partial x^2} + E \frac{\partial A \partial C}{\partial x \partial x} + \frac{\partial E \partial C}{\partial x \partial x} - U \frac{\partial C}{\partial x} - \frac{UC \partial A}{A \partial x} - C \frac{\partial U}{\partial x} - C \frac{\partial A}{\partial t} + R \quad (194)$$

All the terms on the right hand side of this equation can be evaluated. The differentials can be done numerically and the coefficients are fixed by estuary properties.

If $C(x,t)$ is known and $\partial C / \partial t$ at time t can be evaluated, then $C(x, t + \delta t)$ can be found using numerical integration techniques. Specifically, the Runge-Kutta-Mersen method would be used.

Any soluble pollution component can be described by this expression. The only difference in equations from one component to another would be the source and sink term $R(x,t)$. The solution of the overall problem (BOD, NH_3 - NO_2 - NO_3 , OD) would require the solution of a coupled set of about five equations of this form. The equations would be coupled in their respective source and sink terms, $R(x,t)$. That is, BOD, NH_3 , and NO_2 would appear in the $R(x,t)$ term for OD for example.

In the solution of this problem great care should be used in specifying the different source and sink terms and determining the $U(x,t)$ term.

A comparison with previous work can be made by comparing this equation with an equation derived by O'Connor [5] and others. Their equation is derived assuming a constant fresh water flow rate and considering only one point in the tidal phase and is given by

$$\frac{\partial C}{\partial t} = \frac{1}{A} \frac{\partial}{\partial x} \left(EA \frac{\partial C}{\partial x} \right) - U \frac{\partial C}{\partial x} - KC \quad (195)$$

where all the terms are the same with the exceptions that parameters are functions of position only and that the only source or sink considered is the sink of first order absorption of C . This can be compared with a rearranged form of equation (193), derived above

$$\frac{1}{A} \frac{\partial}{\partial t} (AC) = \frac{1}{A} \frac{\partial}{\partial x} \left(EA \frac{\partial C}{\partial x} \right) - \frac{1}{A} \frac{\partial}{\partial x} (UAC) + R. \quad (196)$$

O'Connor claims that for some purposes tidal variation can be ignored since the net effect over a tidal cycle is zero. This might be true in a pseudo-steady state regime but in an estuary which is not at steady state it is not true. Fresh water flow rate, sun light intensities, pollution loads, temperatures, etc. are constantly changing from day to day and especially from season to season. Also, an approach of this type does not permit modeling within a tidal cycle. This is an important limitation if it is necessary to predict the mean within a cycle for some resource management decision.

It can be shown that O'Connor's equation is a special case of the equation derived above. If fresh water flow rate is held constant with time and position (no tributaries) and only solutions at slack tide are considered, then fluid velocity and cross sectional area become functions of position only and

$$U(x) = Q/A(x) \quad (197)$$

where Q is the constant volumetric fresh water flow rate. Then

$$U(x)A(x) = Q \quad (198)$$

and

$$\partial(U(x)A(x))/\partial x = d(U(x)A(x))/dx = 0 \quad (199)$$

If the only source or sink term to be considered is the biological utilization of C , then $R = -KC$.

Now equation (196) can easily be reduced to

$$\frac{1}{A} \frac{\partial(AC)}{\partial t} = \frac{1}{A} \frac{\partial}{\partial x} (EA \frac{\partial C}{\partial x}) - \frac{1}{A} \frac{\partial(UAC)}{\partial x} + R$$

$$\frac{1}{A} (A \frac{\partial C}{\partial t} + C \frac{\partial A}{\partial t}) = \frac{1}{A} \frac{\partial}{\partial x} (EA \frac{\partial C}{\partial x}) - U \frac{\partial C}{\partial x} + \frac{C}{A} \frac{\partial(UA)}{\partial x} - KC$$

or

$$\frac{\partial C}{\partial t} = \frac{1}{A} \frac{\partial}{\partial x} (EA \frac{\partial C}{\partial x}) - U \frac{\partial C}{\partial x} - KC \quad (200)$$

which is O'Connor's equation.

VERIFICATION OF THE STOCHASTIC MODEL

Discussed here are comparisons between predicted values and observed BOD and OD data from the Potomac estuary, the Ohio River and the Delaware estuary.

POTOMAC ESTUARY

In the summer of 1967 an intensive OD and water temperature survey was conducted for the Potomac estuary. These data were made available through the Chesapeake Field Station, Annapolis, Maryland and can be found in the appendix. Sampling was done at four stations which cover the upper 30 miles of the 116 mile estuary. In order to model the estuary, information had to be gathered on all parameters, pollution sources, fresh water sources, etc. for this part of the estuary. Listed in Tables 15, 16, and 17 are the values for the respective parameters, feed rates, etc. which have been used and/or recommended by previous workers.

Table 15: Major pollution sources for the Potomac.

<u>Name</u>	<u>Position, Miles from Chain Bridge</u>	<u>UOD* lbs/day</u>	<u>UOD lbs/hr/square mile</u>
Arlington STP	8.9	43,400	1.507×10^6
D. C. STP	10.0	318,000	1.12×10^7
Alexandria & Westgate STP	12.25	30,100	7.28×10^5
Little Hunting Creek STP	19.6	2,000	3.7×10^4
Dogue Creek	22.0	1,200	1.8×10^4

*Taken from Hetling and O'Connell [36].

Table 16: Various estuary physical parameters for the Potomac

<u>Segment</u>	<u>Position, Miles</u> <u>Beginning</u>	<u>End</u>	<u>K_a**</u> <u>1/hr</u>	<u>V_t*</u> <u>mi/hr</u>	<u>D_B*</u> <u>lbs/hr/cubic mile</u>
1	0.0	2.69	0.00208	0.3863	0
2	2.69	4.78	0.00708	0.4421	14,900
3	4.78	6.53	0.0154	0.4812	150,700
4	6.53	7.84	0.0129	0.5683	301,400
5	7.84	9.71	0.01625	0.8050	273,500
6	9.71	11.82	0.0122	1.042	347,300
7	11.82	14.39	0.01333	1.120	384,500
8	14.39	16.58	0.0104	1.144	279,700
9	16.58	19.02	0.01333	1.168	256,800
10	19.02	21.08	0.00958	1.19	211,500
11	21.08	23.33	0.01083	1.20	159,900
12	23.33	27.33	0.1083	1.20	154,100
13	27.28	30.22	0.1083	1.112	137,600

*Taken from Hetling and O'Connell [36]

**Taken from Custer and Krutchkoff [13]

Table 17: Fresh water velocity component for the Potomac

Location,* Miles from Chain Bridge	Fresh Water** Flow Rate ft/sec.	Cross sectional* Area, ft ²	Fresh Water Velocity, mi/hr.
0.0	5050.	4,605.	0.75
2.69	5050.	30,000.	0.1153
4.78	5050.	24,300.	0.142
6.53	5050.	29,000.	0.119
7.84	5050.	34,300.	0.101
9.71	5050.	32,700.	0.106
11.82	5400.***	47,600.	0.0075
14.39	5400.	49,000.	0.0755
16.58	5400.	43,600.	0.0847
19.02	5400.	59,000.	0.0626
21.08	5400.	66,500.	0.0555
23.33	5400.	84,900.	0.0435
27.28	5400.	111,000.	0.0333
30.22	5400.	130,000.	0.0284

*Hetling and O'Connell [36]

**Taken from unpublished U. S. Dept. of Interior, Geological Survey data

***Increase due to volumetric flow of D.C. STP output as recommended by Hetling and O'Connell [36].

Values for some parameters could not be found as functions of position. The following constant values were taken for EG, EF, DO_{sat} , temperature, K_1 and K_4 (corrected for temperature), and land runoff: 1.042×10^{-1} square miles/hr, 1.042×10^{-1} square miles/hr, 8.0 ppm, 27°C, 0.02/hr., 0.02/hr. and 20000 lbs/hr/cubic mile, respectively.

All these values but land runoff were taken from Custer and Krutchkoff [13]. An estimated value for L_R was necessary since none were available. The solution was not found to be sensitive to the land runoff rate in this range of values.

The upstream, XI, and downstream, XO, boundaries were fixed at 0 and 30 miles from The Chain Bridge, respectively. The minimum numbers of grid points

necessary for a convergent solution of the BOD and OD differential equations were found by experimenting with the program and were set at 120 and 60, respectively. The initial concentrations for both BOD and OD were 0.0 throughout the estuary. The initial time corresponding to this was 0.0 hours. The minimum real time necessary for steady state was found experimentally to be approximately 400 hours. The solution was run for 500 real time hours. The added time was necessary in order to get output through several tidal cycles after pseudo-steady state was reached. Predicted concentrations were printed and punched out every 1.0 real time hour. This relatively small interval was used so that information concerning steady state concentrations within the tidal cycle could be observed.

Notice that an option exists for output in punched card form. This option was utilized in the Potomac verification. The card output of the differential equations program is input to the analysis and limits programs.

Data was printed out at 16 positions. The upstream boundary condition for BOD was fixed at 3.6 ppm using information from Jaworski [40]. The boundary value for OD was arbitrarily selected to be 1.0 ppm from a reasonable range of values. The reaeration rate was made a function of fluid velocity. The option of a variable feed rate was not used as it would have made the model verification more complicated and no data was available over this time period for feed rate as a function of time.

The only adjustment made on this data was to the tidal component of velocity. The values for V_t listed in Table 16 were all multiplied by 1.5 to compensate for using an average cross sectional tidal velocity. This was necessary to account for the fact that the cross sectional velocity gradient is not flat but actually is a somewhat flattened parabolic shape during most of the tidal cycle. The value of 1.5 was selected for two reasons: First, it is the midpoint between no correction, 1.0, and the maximum possible correction, 2.0, (for sampling at the water surface, in the middle of the estuary under conditions of pure laminar flow); and secondly, this value was selected to bring the station results into agreement with observed data. With this done it was found that the other stations were in essential agreement also.

The difficulties of using cross sectional average velocities was recognized by Feigner and Harris [20a, page 20]. Using this data the estuary was modeled. It was found that from the Chain Bridge down through the 15th or 20th mile that there was relatively good agreement with the observed data but from the 20th through the 30th mile, there was little agreement. In the lower section (20-30 miles) the predicted concentrations both dropped to near zero values, as all the BOD was oxidized and OD eliminated, while the observed values remained at levels of 3.0, to 5.0 ppm OD. It was pointed out in the model discussion that this is what would be expected if the parallel series reaction were taking place instead of the simple series reaction. Processes which are taking place in the estuary are not being accounted for in the model. This led to some disagreement in the upper section (0-20 miles) because photosynthesis is not being considered, but carbon and nitrogen recycling is not yet important. However, in the lower section a great deal of disagreement between the predicted and observed values occurs because the interacting processes of photosynthesis, algal growth and death (or carbon and nitrogen recycling through organic form), NH_3 - NO_2 - NO_3 series reaction etc. have become important.

For these reasons it was decided to make no attempt to verify the model beyond the 20th mile and to adjust the predicted values above 20 miles for photosynthesis when necessary so that the average predicted concentration over a full tidal cycle was the same as the mean observed concentration over a tidal cycle. The adjustment necessary for OD were -0.10 ppm for station 1, -0.55 ppm for station 2, +0.48 ppm for station 3 and station 4 was omitted because it was below the 20th mile. Although these adjustments are not large, adjustments of this type should not be necessary in an estuary model. This is strong evidence that the nitrogen and algae processes should be included in the estuary model. Inspection of the adjustment for station 3 indicates that the lack of the recycling processes has had some effect as far up as the station 3 (17.8 miles). Plots comparing the observed average concentrations

to the adjusted predicted values for stations 1, 2, and 3 are shown in Figures 18, 19, and 20. Inspection of the figures indicates an excellent fit to the stations 1 and 2 data and a good fit for station 3. The concentrations for station 3 are very near the maximum oxygen deficit level. This indicates that for at least short periods of time, there were anaerobic conditions. For this reason some lack of fit is expected.

The Δ program was used to calculate Δ values for the four stations. As mentioned in the stochastic component section the resulting average station values were as given in Table 18.

Table 18: Average values of Δ by station.

<u>Station 1</u>	<u>Station 2</u>	<u>Station 3</u>	<u>Station 4</u>
0.2260	0.2603	0.0254	0.2022

Table 19 is a summary of the Δ values as broken into tidal phase subclasses.

Table 19: Δ values by tidal subclass.

<u>Tidal Class</u>	<u>Station 1</u>	<u>Station 2</u>	<u>Station 3</u>	<u>Station 4</u>
1	0.167	0.372	0.041	0.382
2	0.191	0.175	0.046	0.532
3	0.185	0.194	0.043	0.648
4	0.131	0.097	0.022	0.040
5	0.253	0.137	0.001	0.015
6	0.270	0.104	0.001	0.002
7	0.226	0.329	0.064	0.182
8	0.453	0.666	0.053	0.194
9	0.239	0.188	0.008	0.009
10	0.133	0.263	0.018	0.027
11	0.131	0.232	0.003	0.079
12	0.334	0.367	0.004	0.315

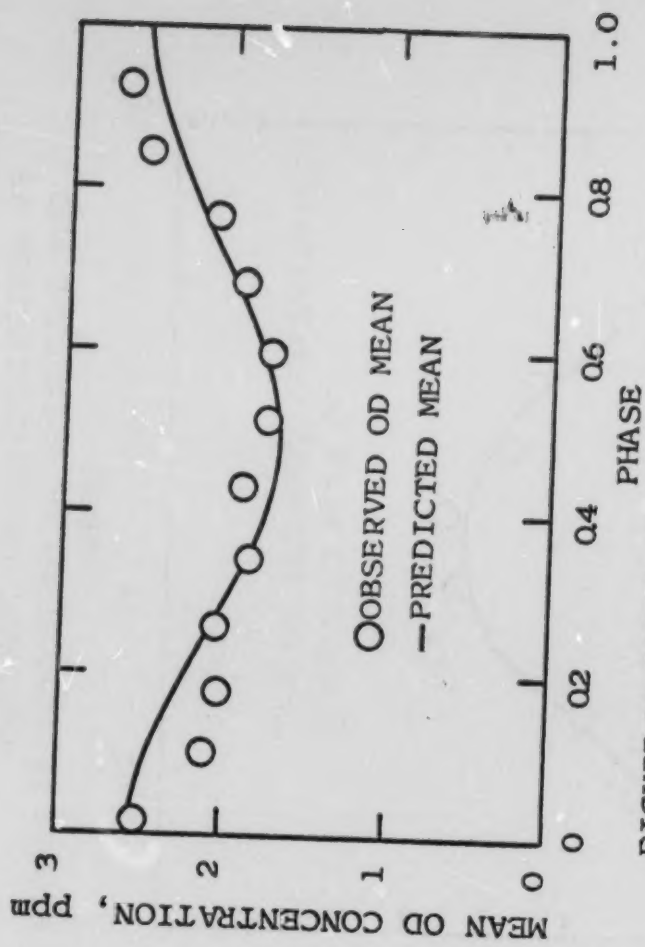


FIGURE 18 COMPARISON OF PREDICTED AND OBSERVED OD CONCENTRATION AS FUNCTIONS OF TIDAL CYCLE FOR STATION 1, POTOMAC ESTUARY

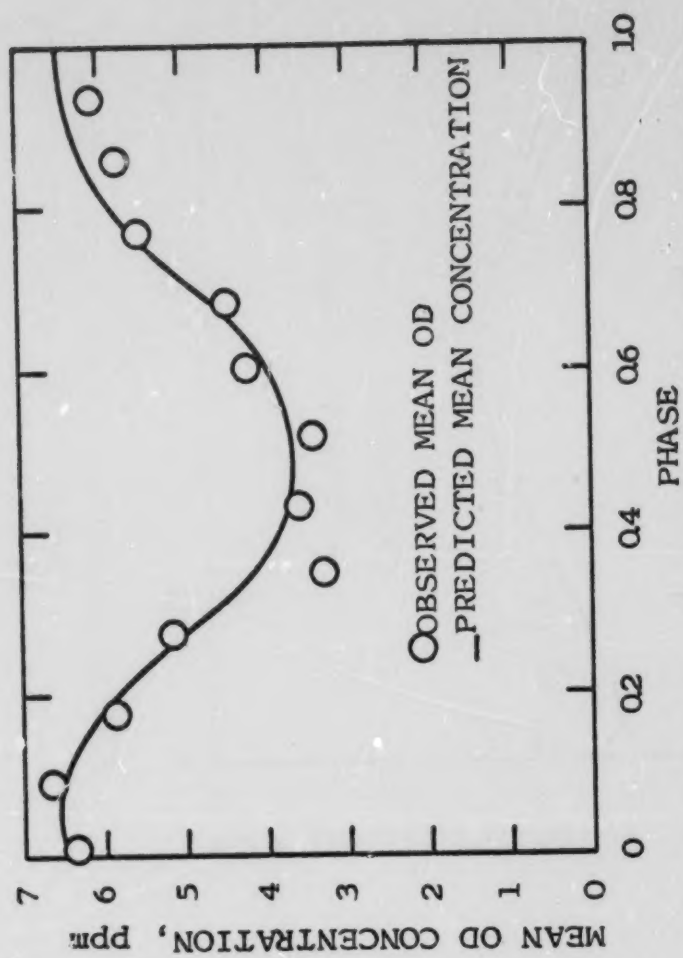


FIGURE 19 COMPARISON OF PREDICTED AND
OBSERVED OD CONCENTRATION AS
FUNCTIONS OF TIDAL CYCLE FOR
STATION 2, POTOMAC ESTUARY

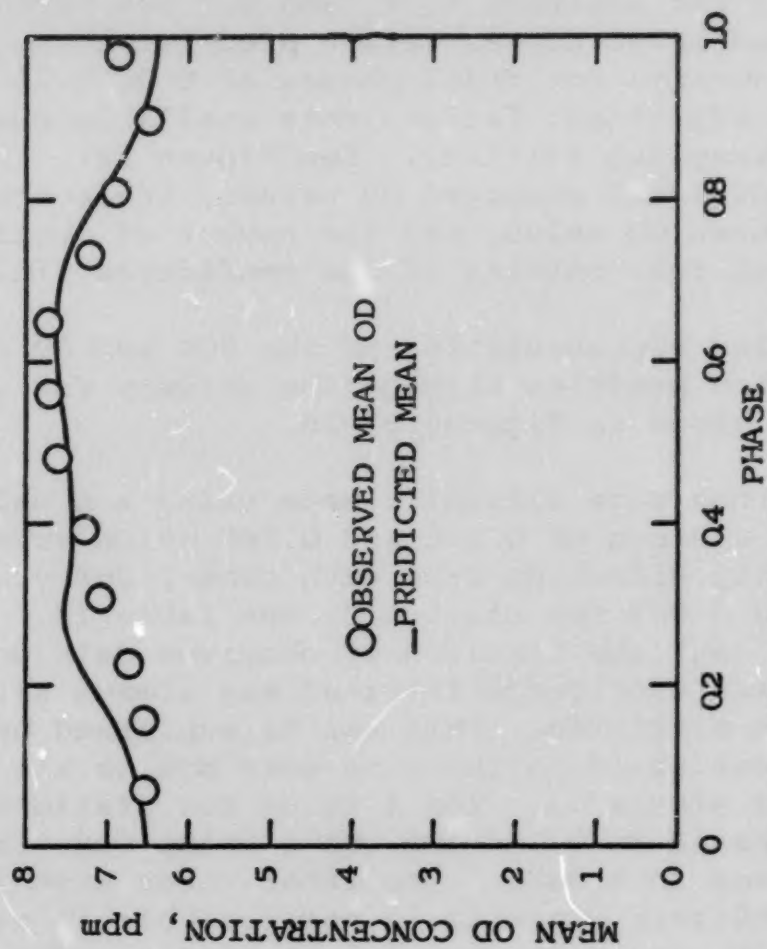


FIGURE 20 COMPARISON OF PREDICTED AND OBSERVED OD CONCENTRATION AS FUNCTIONS OF TIDAL CYCLE FOR STATION 3, POTOMAC ESTUARY

The card output of the differential equations program along with individual observed OD values provided by WQO were used as input to the analysis program. The adjustment to the predicted means were included internally in the program. The analysis program gave the following output:

1. Adjustment concentration profiles through a tidal cycle for stations 1, 2, and 3. See Figure 21.
2. Unadjusted concentration profiles through the upper section for tidal phases of 0.0, 0.25, 0.50, and 0.75. Adjustment factors were available only at the three sampling stations. See Figure 22.
3. Individual observed OD values, the corresponding predicted mean OD value, and the number of observed values which fell outside of the confidence limits.

More detailed representation of the BOD and OD mean concentration profiles through the estuary for various phases are shown in Figures 23-26.

These runs were initially made using a Δ value of 0.243 (the average of 0.226 and 0.260 which were not significantly different from each other) for stations 1 and 2 and 0.025 for station 3. See Table 18. The result was that the fraction of observed data outside the predicted confidence interval was always slightly higher than predicted. This can be explained by the amount of variation in the true mean due to all other sources not simulated. The Δ value for stations 1 and 2 was increased to 0.275 and the Δ value for station 3 was increased to 0.0475. The final value used is obviously arbitrary since it is not possible to estimate the variance component due to lack of fit. The results then yielded slightly lower fractions predicted than observed indicating that this was an over-correction. However, no further adjustment was made. The results are shown in Table 20.

A pictorial comparison of the predicted mean and confidence limits and the individual observations are shown in Figures 27, 28 and 29.

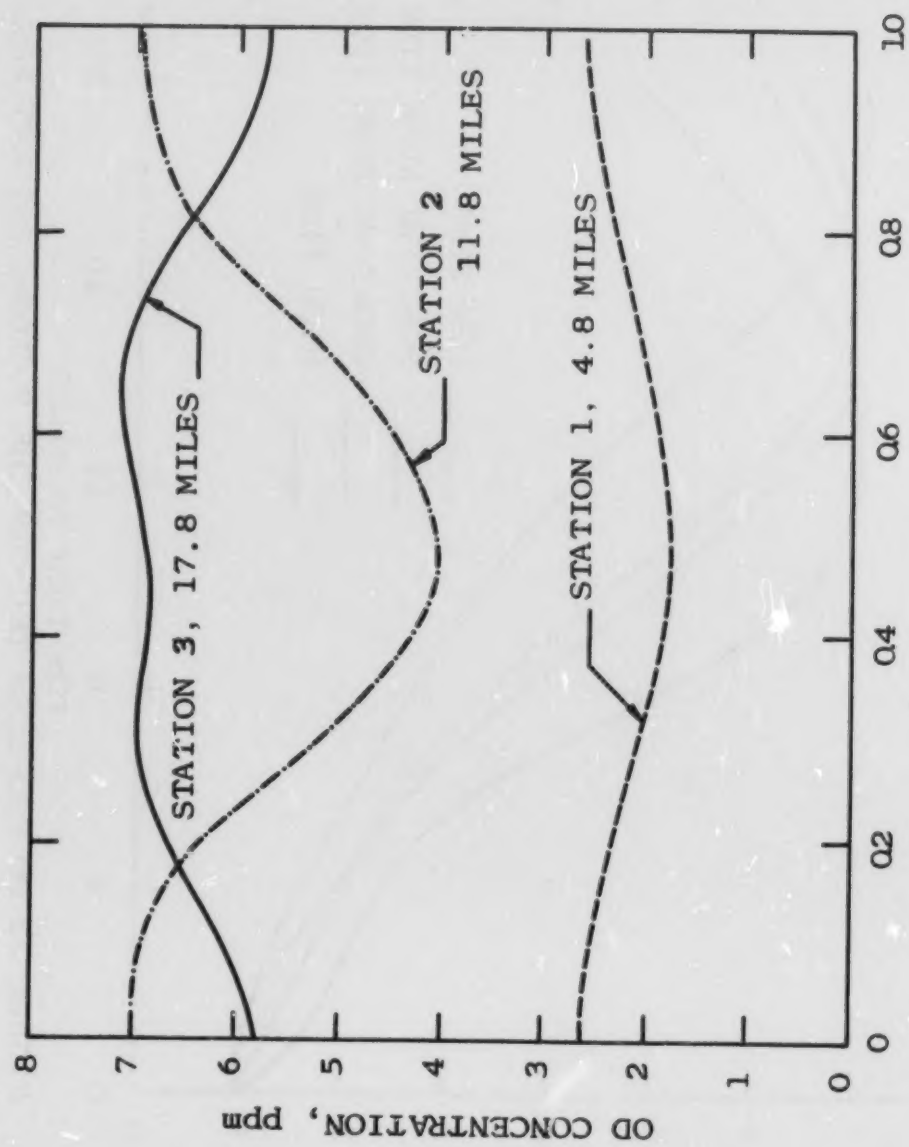


FIGURE 21 OD PROFILES THROUGH TIDAL PHASE FOR 3 STATIONS IN THE POTOMAC ESTUARY

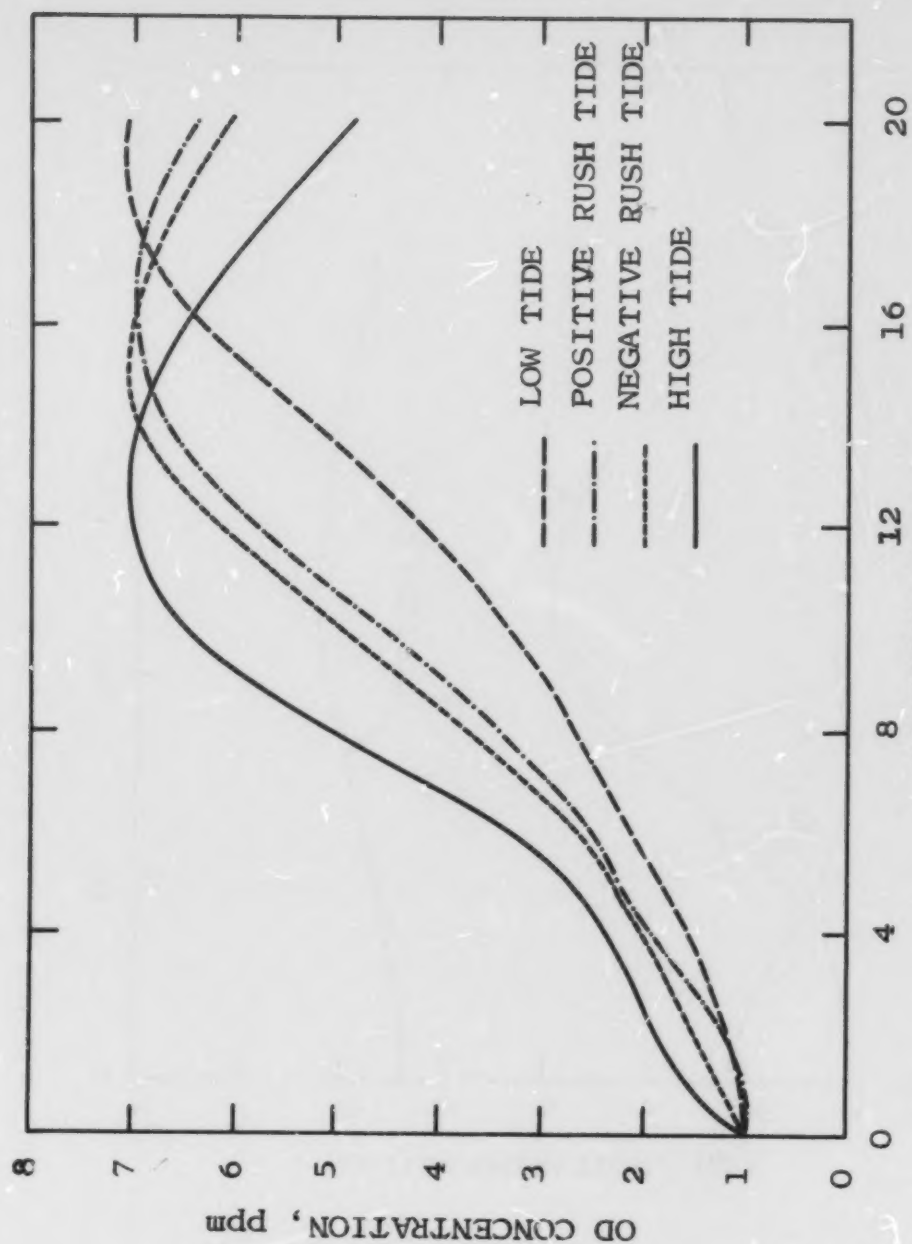
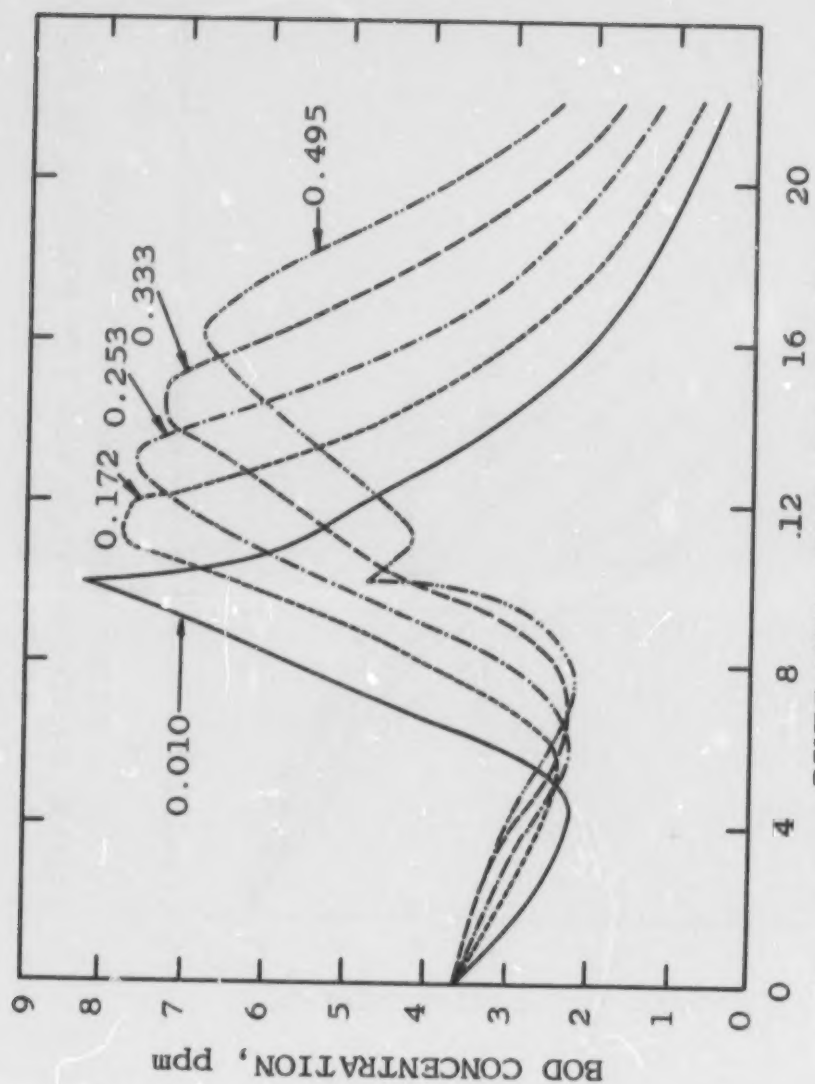


FIGURE 22 OD PROFILES THROUGH THE POTOMAC ESTUARY FOR 4 TIDAL PHASES



RIVER MILE FROM CHAIN BRIDGE
 FIGURE 23 BOD PROFILES FOR THE POTOMAC ESTUARY
 AS FUNCTIONS OF TIDAL PHASE (0.01 TO
 0.495)

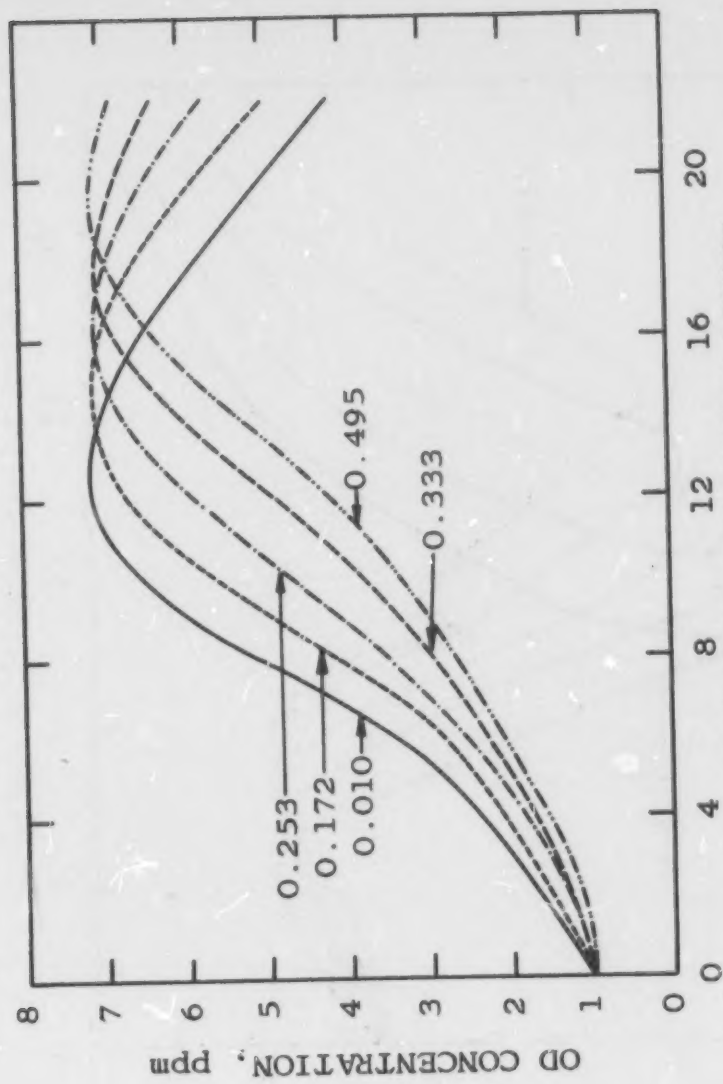


FIGURE 24 OD PROFILES FOR THE POTOMAC ESTUARY
AS FUNCTIONS OF TIDAL PHASE (0.010 TO
0.495)

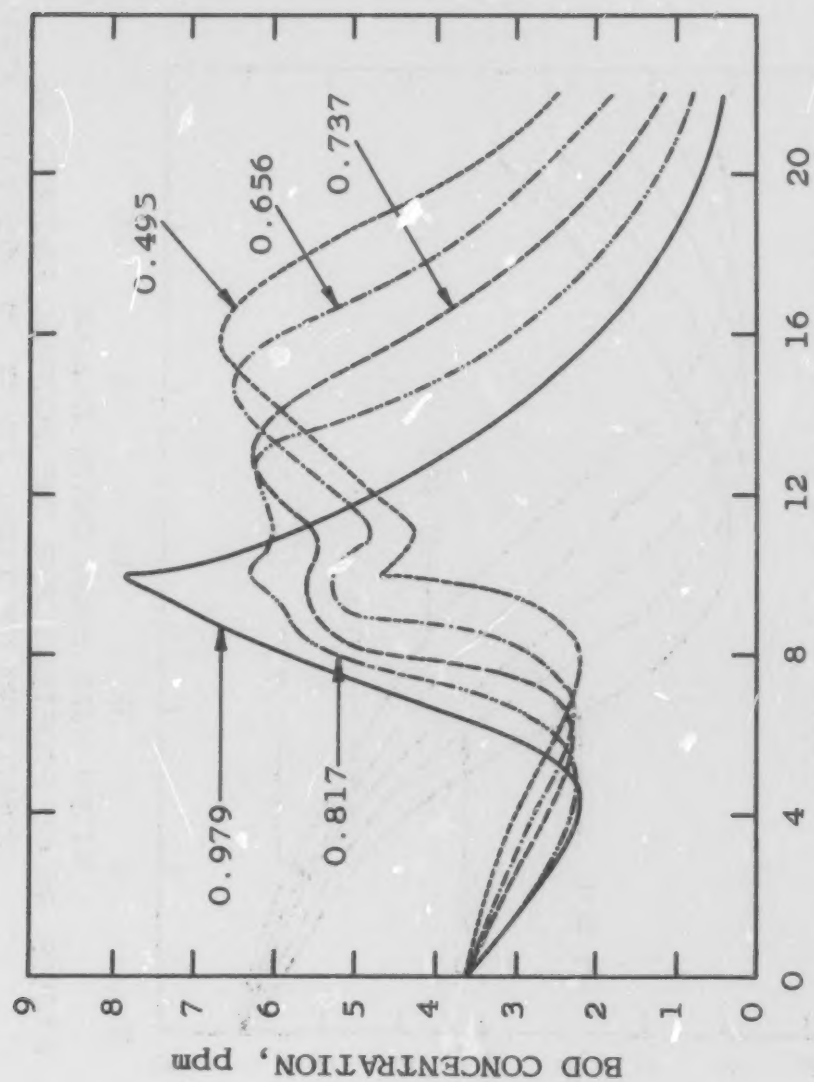


FIGURE 25 BOD PROFILES FOR THE POTOMAC ESTUARY
AS FUNCTIONS OF TIDAL PHASE (0.495 TO
0.979)

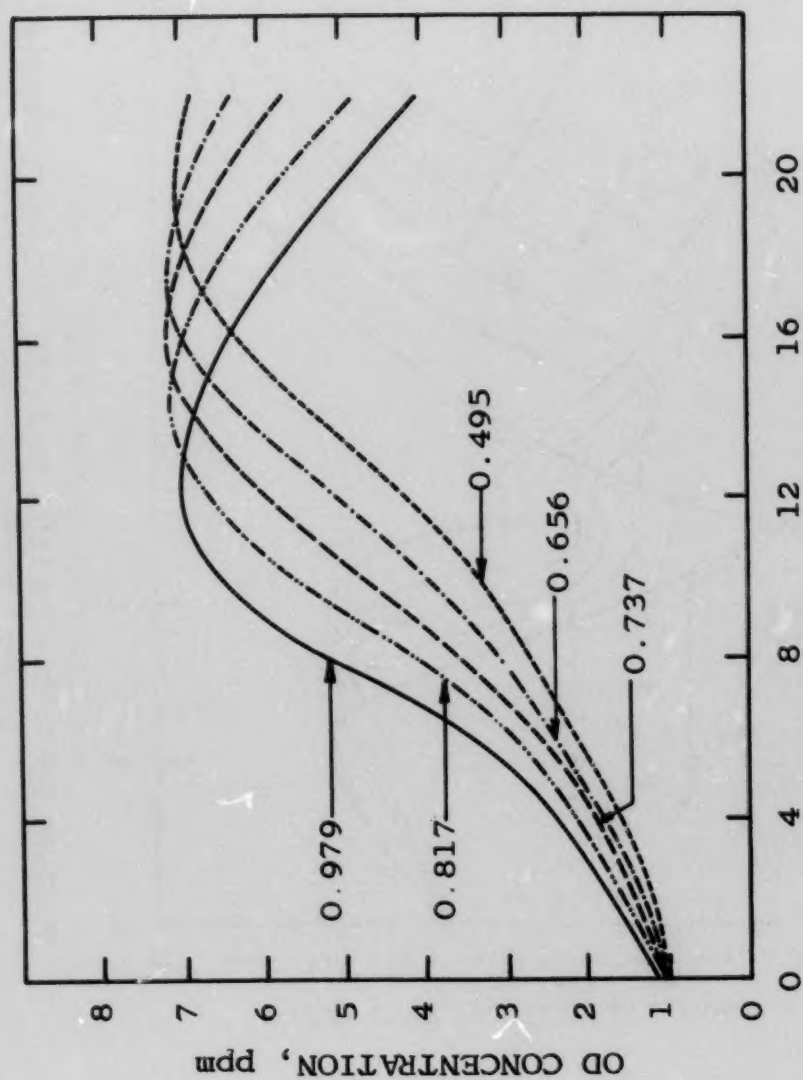


FIGURE 26 OD PROFILES FOR THE POTOMAC ESTUARY AS
FUNCTIONS OF TIDAL PHASE (0.495 TO 0.979)

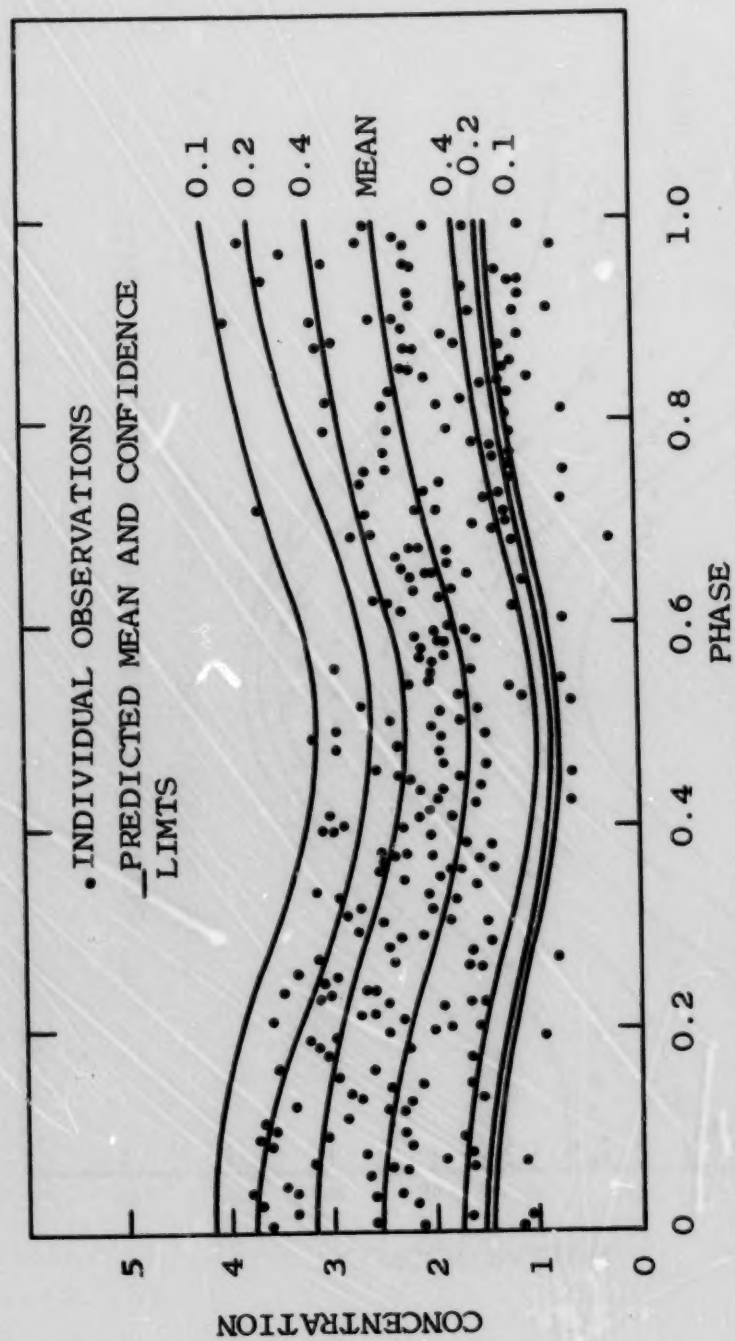


FIGURE 27 COMPARISON OF PREDICTED MEAN OD CONCENTRATION AND
CONFIDENCE LIMITS WITH OBSERVED OD DATA AS FUNCTIONS
OF TIDAL CYCLE FOR STATION NO 1, POTOMAC ESTUARY

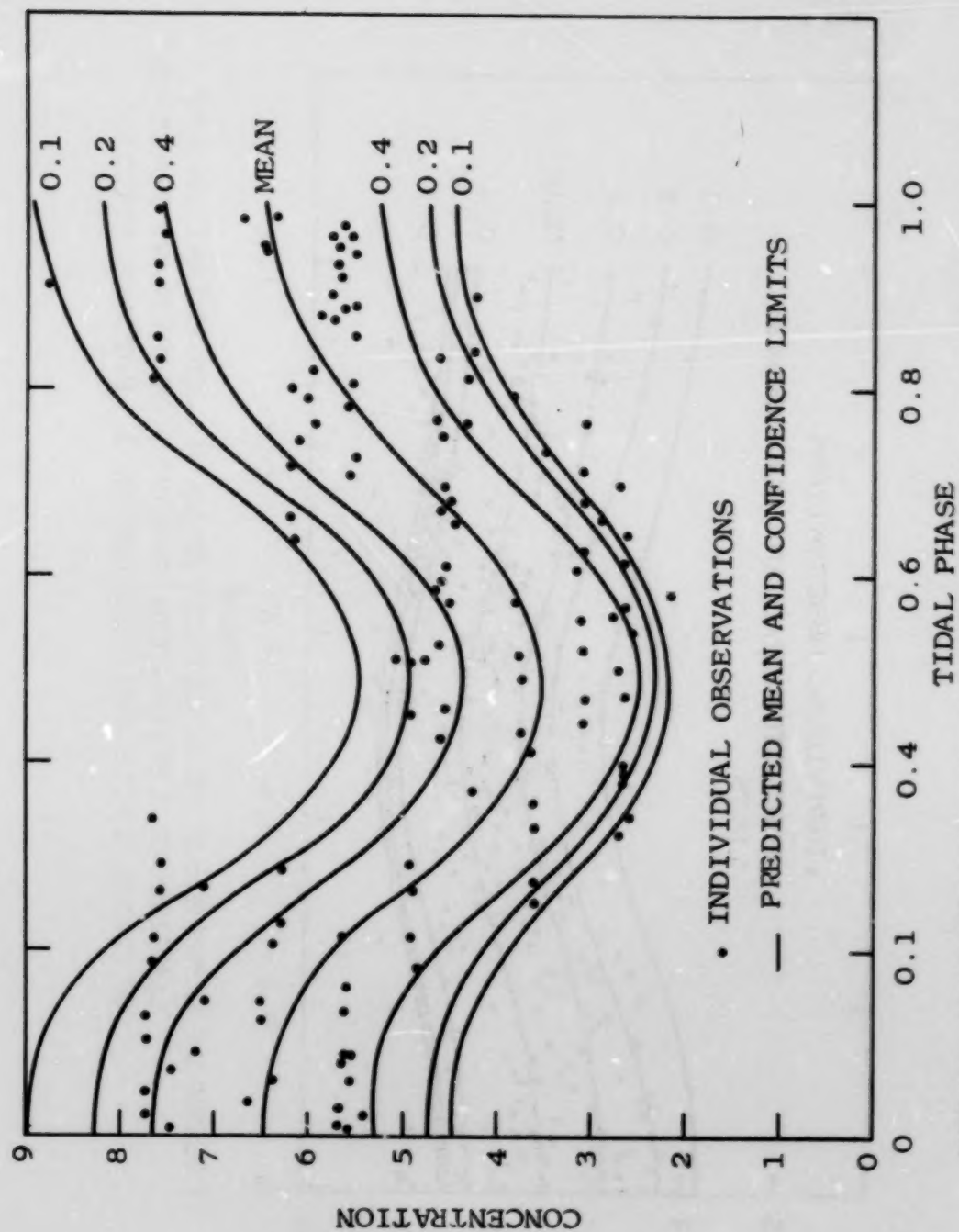


FIGURE 28 COMPARISON OF PREDICTED MEAN OD CONCENTRATION AND CONFIDENCE LIMITS WITH OBSERVED OD DATA AS FUNCTIONS OF TIDAL CYCLE FOR STATION NO.2, POTOMAC ESTUARY

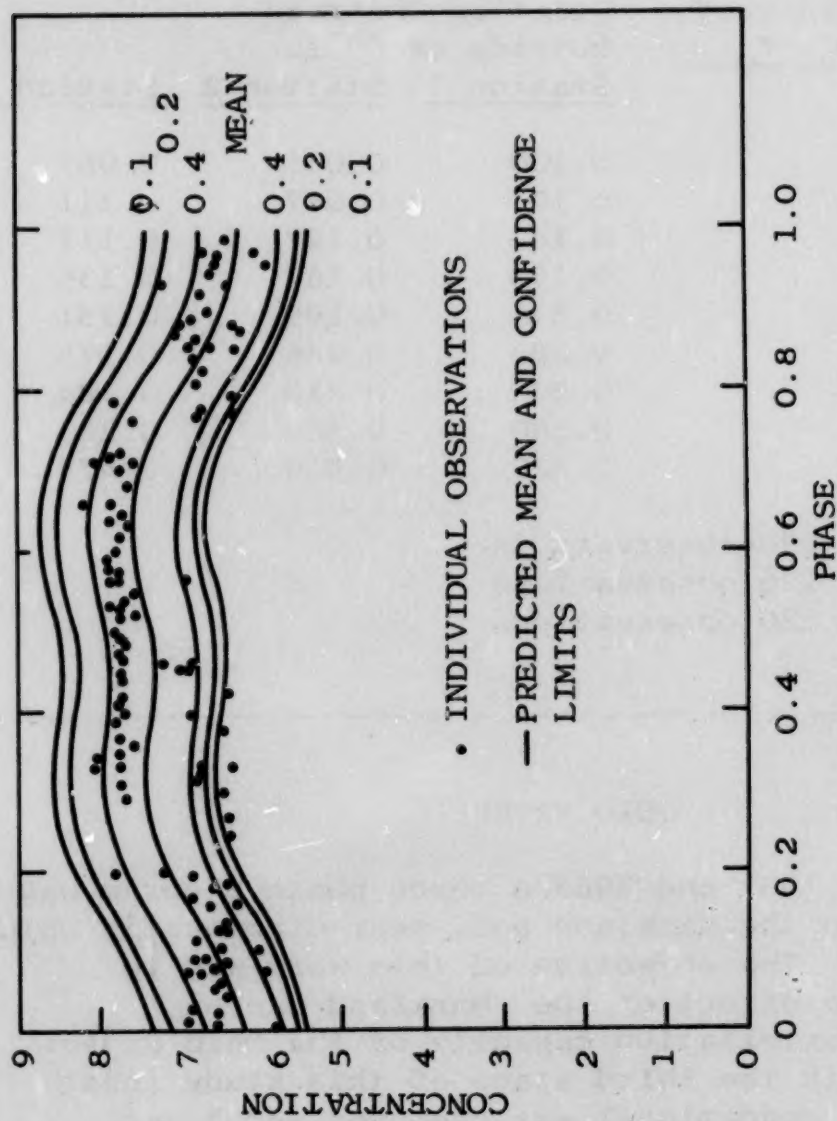


FIGURE 29 COMPARISON OF PREDICTED MEAN OD CONCENTRATION AND CONFIDENCE LIMITS WITH OBSERVED OD DATA AS FUNCTIONS OF TIDAL CYCLE

Table 20: Observed vs. predicted fraction of values
outside specified concentration confidence
interval for the Potomac Estuary

<u>Fraction Predicted Outside of C. I.</u>	<u>Fraction Observed Outside of C. I.</u>		
	<u>Station 1</u>	<u>Station 2</u>	<u>Station 3</u>
0.05	0.100	0.055	0.087
0.10	0.10	0.087	0.111
0.15	0.141	0.127	0.111
0.20	0.193	0.167	0.135
0.25	0.242	0.199	0.151
0.30	0.285	0.246	0.175
0.35	0.335	0.310	0.184
0.40	0.380	0.365	0.230
0.50	0.470	0.500	0.477

Station 1 - 270 observations
Station 2 - 126 observations
Station 3 - 126 observations

OHIO RIVER

Between 1957 and 1963 a three phase program was conducted on the Markland pool near Cincinnati, Ohio (see [12]). The objective of this work was to evaluate the effect of the Markland dam on the waste assimilation capacity of the Ohio River. Data taken in the third stage of this study (post-impoundment conditions) was used for model verification. Individual BOD and DO samples were taken every 3 hours at 8 stations in the Markland pool at two depths. To help insure the validity of the uniform cross sectional concentration assumptions, the average sample value over the two depths was always used. The section of the river between the Southern Railroad Bridge at Cincinnati (river mile 472.3) and a point just below the great Miami River confluence (river mile 492.3) was modeled.

The information used in the study is given in Tables 21, 22, and 23.

Table 21: STP outputs for the Ohio River.

<u>STP</u>	<u>Location</u>	<u>Cross Sectional Area</u>	<u>Pollution Load*</u>
Mill Creek	472.55	41,290 ft ²	135,450 lbs/day
Bromley	474.00	44,560 ft ²	27,020 lbs/day
Muddy Creek	481.45	45,000 ft ²	5,500 lbs/day

*These values reflect first stage BOD loadings only. This creates no difficulty since the nitrification process is not important in the section of the river being modeled.

Table 22: Physical and biological information for the Ohio River.

<u>Variable or Parameter</u>	<u>Value</u>
average temperature	24°
saturated O ₂ conc.	8.25 ppm
upstream boundary condition	
BOD	1.78 } Taken from observed
OD	1.72 } data stations 1 and 2
K ₁	0.16 day (adjusted to 24°C)
K ₂	0.05/day
average volumetric flow rate	14,800 ft ³ /sec
diffusion coefficient	0.24 mile ² /hr
L _R	0.0 lbs/mile ³ /hr
D _B	30,000 lbs/mile ³ /hr
adjustment to K ₂ (x)	none
tidal velocity	none
BOD and OD grid spacing	1/4 mile
steady state time	140-200 hours
time variation of feed rate	none

Table 23: Fluid velocity as a function of position for the Ohio River.

<u>Position, river mile</u>	<u>Velocity miles/hour</u>
472.35	0.269
472.55	0.244
472.60	0.226
477.55	0.236
481.45	0.224
482.65	0.196
486.80	0.217
489.60	0.194
491.20	0.262
492.30	0.226

The only change necessary in these values for modeling was in the $K_1(x)$ rate. The observed BOD data indicated a very fast utilization of BOD in the river just below the Mill Creek outfall. To reflect this in the model, a K_1 rate 5 times the suggested value was used for the first 4 miles below Mill Creek and a value twice the suggested value was used for the next 8 miles. The suggested value was found adequate for the remaining 8 miles. This somewhat empirical changing of the K_1 was done to make the predicted profile for the mean BOD concentrations agree with the observed values. A test of this procedure can be made now by seeing how closely the predicted OD profile fits the observed OD concentration. If a close fit is obtained it is probable that the method used above is correct. The fit obtained was good as can be seen in Figure 30.

Thus it can be seen that this model can accurately predict mean concentrations when the nitrogen processes are not important.

Now that the mean concentration has been predicted, the predicted distribution around the mean must be

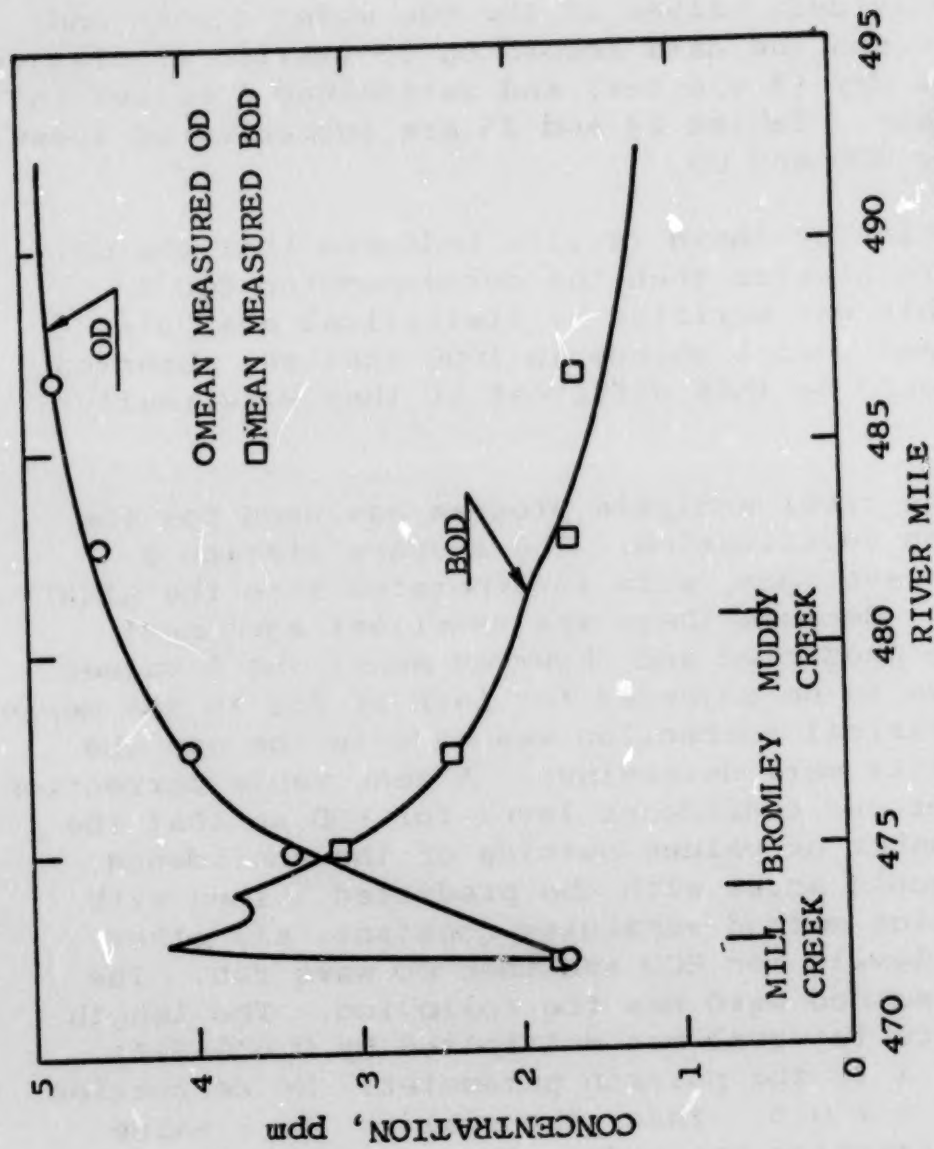


FIGURE 30 A COMPARISON OF PREDICTED AND OBSERVED
BOD AND OD MEAN CONCENTRATIONS IN THE
MARKLAND POOL OF THE OHIO RIVER

verified. Since the more elaborate Δ predicting program had not yet been completed, the river Δ program was used. The individual BOD and OD values were fed to the program for stations 2 through 8. The program averaged the two individual values at the two water depths and then subdivided the data according to station (7 classes) and time of day (8 classes) and determined Δ values in each subclass. Tables 24 and 25 are summaries of these results for BOD and OD.

Inspection of these results indicate that the OD Δ values are greater than the corresponding BOD Δ values. This was verified by statistical analysis. There is less than 1 chance in 1000 that the observed Δ values would be this different if they were really equal.

Next the river analysis program was used for the distribution verification. The average station Δ values, row averages, were incorporated into the LIMRIV subroutine. Because there was excellent agreement between the predicted and observed means, the Δ values did not have to be adjusted for lack of fit to the means. Also an empirical correction was made to the way the poisson limits were determined. A reasonable correction was made for one confidence level for BOD so that the observed number of values outside of the confidence interval should agree with the predicted. Then with the correction method remaining constant, all other confidence levels for BOD and then OD were run. The correction method used was the following. The length of confidence interval was multiplied by $0.6(0.5-\lambda)$ if $\lambda < 0.5$, λ is the poisson parameter. No correction was made if $\lambda \geq 0.5$. Thus, the smaller the λ value the more correction was made. The results obtained this way were quite good and are given in Table 26.

These results are very good. Both the mean concentrations and the distributions about these means have been very closely fit.

Table 24: A summary of Δ values for BOD for the Ohio River

Station NO.	Time of Day Classification								Row Average
	1	2	3	4	5	6	7	8	
2	0.049	0.085	0.124	0.124	0.076	0.045	0.067	0.030	0.074
3	0.140	0.107	0.097	0.143	0.138	0.135	0.176	0.145	0.135
4	0.200	0.172	0.171	0.152	0.147	0.213	0.159	0.111	0.166
5	0.064	0.181	0.345	0.255	0.143	0.157	0.095	0.079	0.165
6	0.090	0.237	0.236	0.307	0.133	0.131	0.087	0.077	0.162
7	0.031	0.041	0.089	0.069	0.062	0.087	0.067	0.089	0.067
8	0.035	0.049	0.056	0.062	0.039	0.073	0.055	0.063	0.054
colm aver.	0.087	0.125	0.160	0.159	0.105	0.120	0.100	0.085	0.118*

*The overall average BOD Δ value.

Table 25: A summary of Δ values for OD for the Ohio River.

Station No	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	Row Average
2	0.107	0.140	0.102	0.206	0.099	0.102	0.104	0.142	0.125
3	0.112	0.152	0.267	0.309	0.242	0.268	0.156	0.102	0.201
4	0.206	0.183	0.284	0.247	0.269	0.223	0.182	0.104	0.212
5	0.258	0.204	0.217	0.181	0.118	0.200	0.254	0.270	0.214
6	0.242	0.185	0.202	0.195	0.192	0.225	0.192	0.223	0.207
7	0.130	0.095	0.115	0.098	0.124	0.198	0.177	0.102	0.130
8	0.087	0.084	0.097	0.100	0.102	0.134	0.140	0.097	0.105
colm aver.	0.163	0.149	0.183	0.191	0.164	0.193	0.172	0.150	0.171*

*The overall average OD Δ

Table 26: Observed vs. predicted fraction of values outside specified concentration confidence intervals for the Ohio River.

Fraction Predicted Outside of C. I.	Fraction Observed Outside of C. I. by Station							
	3	4	5	6	7	8		
<u>BOD</u>								
0.10	0.148	0.045	0.082	0.148	0.126	0.133		
0.15	0.185	0.141	0.156	0.170	0.141	0.200		
0.20	0.236	0.274	0.163	0.230	0.245	0.252		
0.30	0.333	0.318	0.245	0.304	0.311	0.296		
0.40	0.429	0.485	0.362	0.429	0.415	0.429		
0.50	0.563	0.510	0.532	0.541	0.445	0.490		
<u>OD</u>								
0.10	0.140	0.096	0.104	0.111	0.111	0.140		
0.15	0.163	0.126	0.148	0.126	0.119	0.156		
0.20	0.208	0.222	0.170	0.170	0.140	0.192		
0.30	0.341	0.318	0.296	0.267	0.215	0.267		
0.40	0.378	0.400	0.415	0.407	0.349	0.341		
0.50	0.452	0.482	0.482	0.490	0.467	0.437		

Station 1 and 2 were not used since their values had been used as upstream boundary conditions. There were 135 observations/station

DELAWARE ESTUARY

Initially it was planned to model the Delaware Estuary as was done for the Potomac Estuary and Ohio River. However, a lack of sufficient DO and BOD sample values taken over a short period of time was not available for verification of the stochastic model.

Listed in Tables 27, 28, and 29 is that information which was found and which would be good starting information for modeling the Delaware.

Table 27: Physical and biological data for the Delaware

<u>Variable</u>	<u>Value</u>
Upstream boundary conditions	
BOD	2.0 ppm
OD	1.0 ppm
Correction for $K_2(x)$	yes
K_1 and K_d	0.017 hr
L_R rate	0.0 lbs/mile ³ /hr
D_B rate	0.0 lbs/mile ³ /hr

It would be useful to make a comment here concerning the amount of work necessary in doing this modeling. The first time that a particular stream or estuary is modeled a great deal of time is required to find information which is pertinent to this model. This is true for several reasons including the fact that this model is quite different from the presently used model and that this is a stochastic model which requires many OD and/or BOD observations for verification. The important point is that once a stream or estuary has been modeled, additional work can be done quite quickly.

Table 28: Fresh water flow rate for the Delaware

Position Miles from arbitrary Point 10 miles above Trenton, N. J.	Flow Rate <u>miles/hr</u>
10.00	0.479
13.79	0.205
17.57	0.156
21.36	0.136
25.15	0.118
28.93	0.10
32.72	0.0805
34.62	0.0676
36.51	0.066
38.40	0.0613
40.29	0.0593
42.19	0.0561
44.08	0.0554
46.00	0 050

Table 29: Reaeration rate for the Delaware

Position Miles from point 10 miles above Trenton, N. J.	Reaeration rate <u>1/hrs</u>
11.90	0.027
15.69	0.015
19.47	0.0096
23.26	0.0096
27.04	0.0067
33.67	0.0092
35.56	0.0092
37.46	0.0067
39.35	0.0067
41.24	0.0067
43.14	0.0050
45.03	0.0050

USING THE MODEL: CASE STUDIES

Frequently when a physical system is being analyzed the question is raised, "What if...". In our case, what would happen to the pollution and oxygen deficit levels in a particular estuary if some specific change were made in it. In this section several of these questions are answered for the Potomac estuary and the method of answering others will be demonstrated using the model developed in this work.

The first set of variations to be considered is the method of introducing the pollution into the estuary. Several variations in the method of introducing the pollution are considered here:

I Introduce pollution at the current STP positions but at a rate proportional to the fluid velocity at the STP outfalls. This will permit maximum dilution given that the outfalls are fixed.

II. Introduce it at a constant rate into the river just above the tidal portion. This may permit more uniform dispersion.

III. Introduce it as a line source over the upper 30 miles of the estuary. This method would permit uniform loading and prevent one section being over loaded

IV. Introducing it at a constant rate at the present STP outfalls.

For lack of better information, Case IV is considered the method of present operation. The simulation of Case I is accomplished by multiplying the feed rates of the standard, Case IV, by $1.5708|\sin(\omega t)|$. This is the same factor used to make the reaeration rate constant proportional to tidal velocity.

Case II is simulated by calculating the pollution concentration if all the pollution were introduced into the river beyond any tidal effect. The concentration of pollution from upstream is added to this

and the sum in ppm is used as the upstream BOD boundary condition.

Case III is simulated by dividing the pollution rate, in lb-BOD/hr by the estuary volume in cubic miles and incorporating the result in to the model as land runoff.

The BOD and OD profiles at high tide resulting from this simulation are shown in Figures 31 and 32 respectively. A brief inspection of these figures indicates that Case I has little effect. Case II has a strong detrimental effect. Introducing the pollution above the tidal section would not be a good idea. Case III, uniform loading, seems to yield a large improvement in the maximum oxygen deficit.

Next a series of three run groups are shown and discussed. In each group a process parameter or condition will be set at its standard level, one half its standard level and twice its standard level.

First to be considered is reaeration rate K_2 . The results, at high tide, obtained for this group of runs are shown in Figures 33 and 34. Inspection of the BOD curve indicates that anaerobic conditions would be reached if K_2 were reduced by 50%. Where the OD profile would drop below 8 ppm (0 dissolved oxygen) is not known. The small differences in the BOD curves are due more to the fact the different data plotted was not all taken at exactly the same phase value but ranged from 0.99 to 1.01. The BOD curve which would actually result for the $\frac{1}{2}K_2$ case is not known since this is not an anaerobic model.

Next to be considered is the biological utilization rate K_1 , see Figures 35 and 36. The expected result of quicker utilization of BOD with a greater K_1 value is seen in the BOD curve. The OD curve indicates a quicker and higher OD peak with greater K_1 rates, as would be expected.

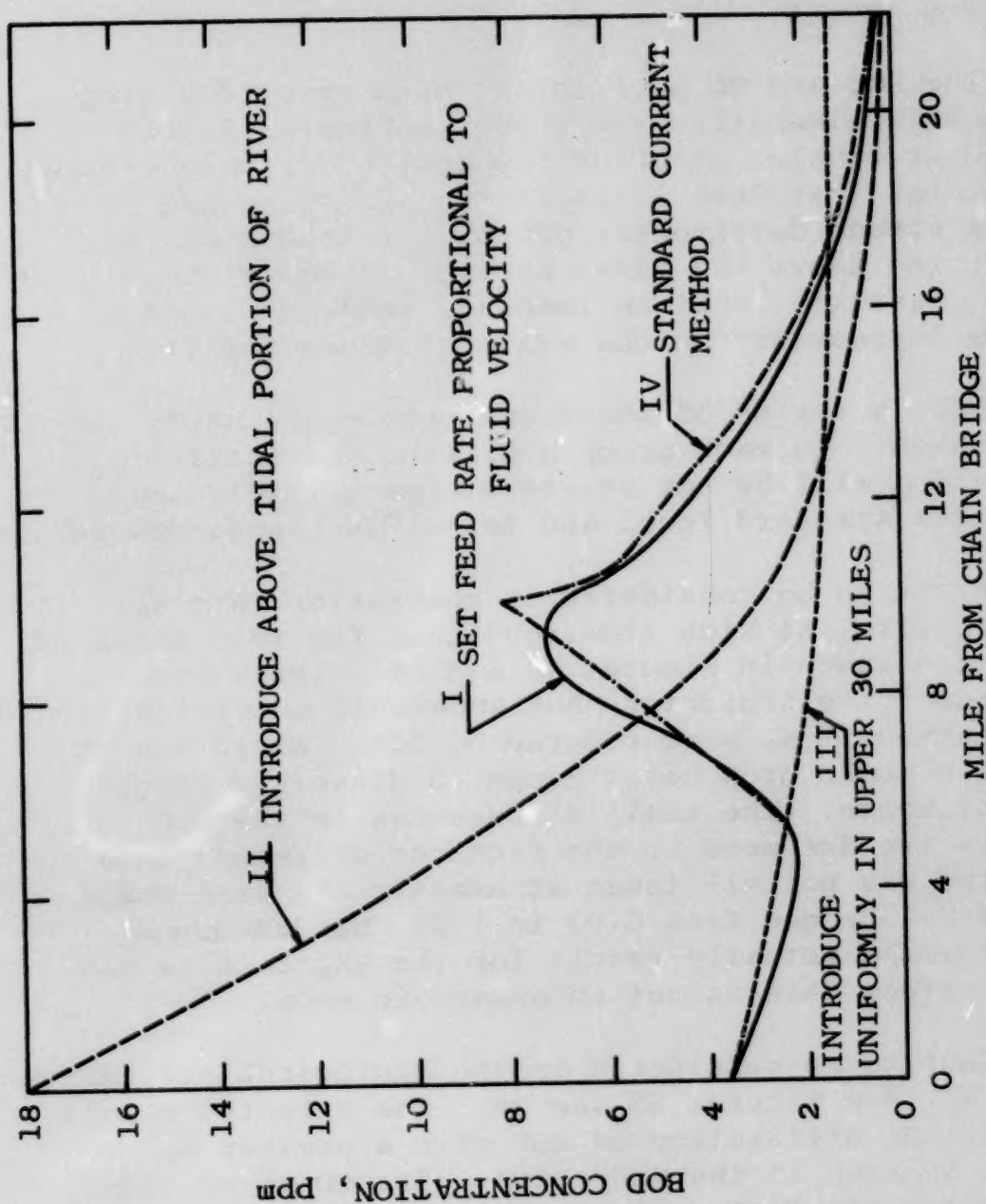


FIGURE 31 BOD PROFILES RESULTING FROM FOUR DIFFERENT METHODS OF INTRODUCING POLLUTION TO THE POTOMAC ESTUARY

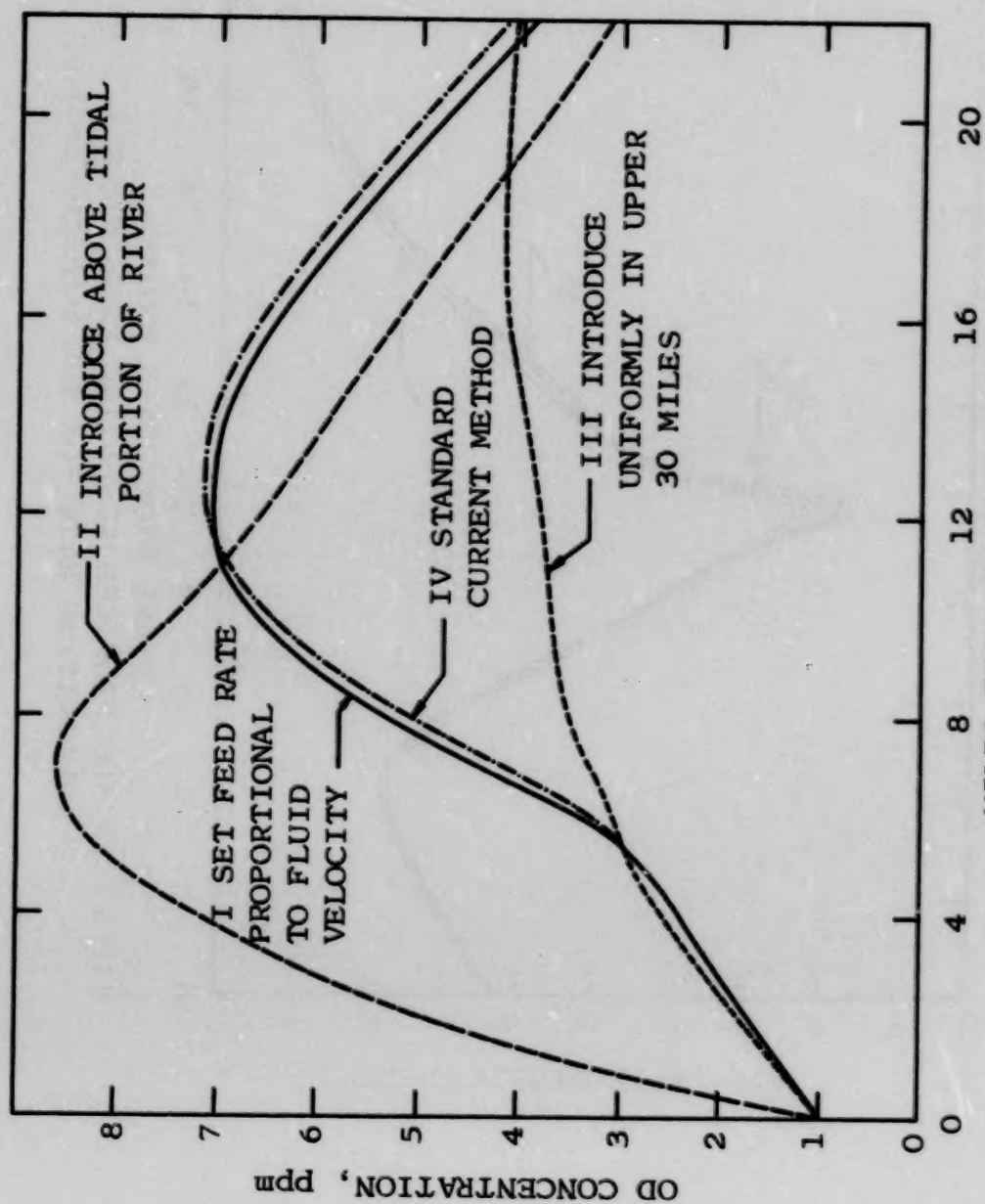


FIGURE 32 OD PROFILES RESULTING FROM FOUR DIFFERENT METHODS OF POLLUTION INPUT TO THE POTOMAC ESTUARY

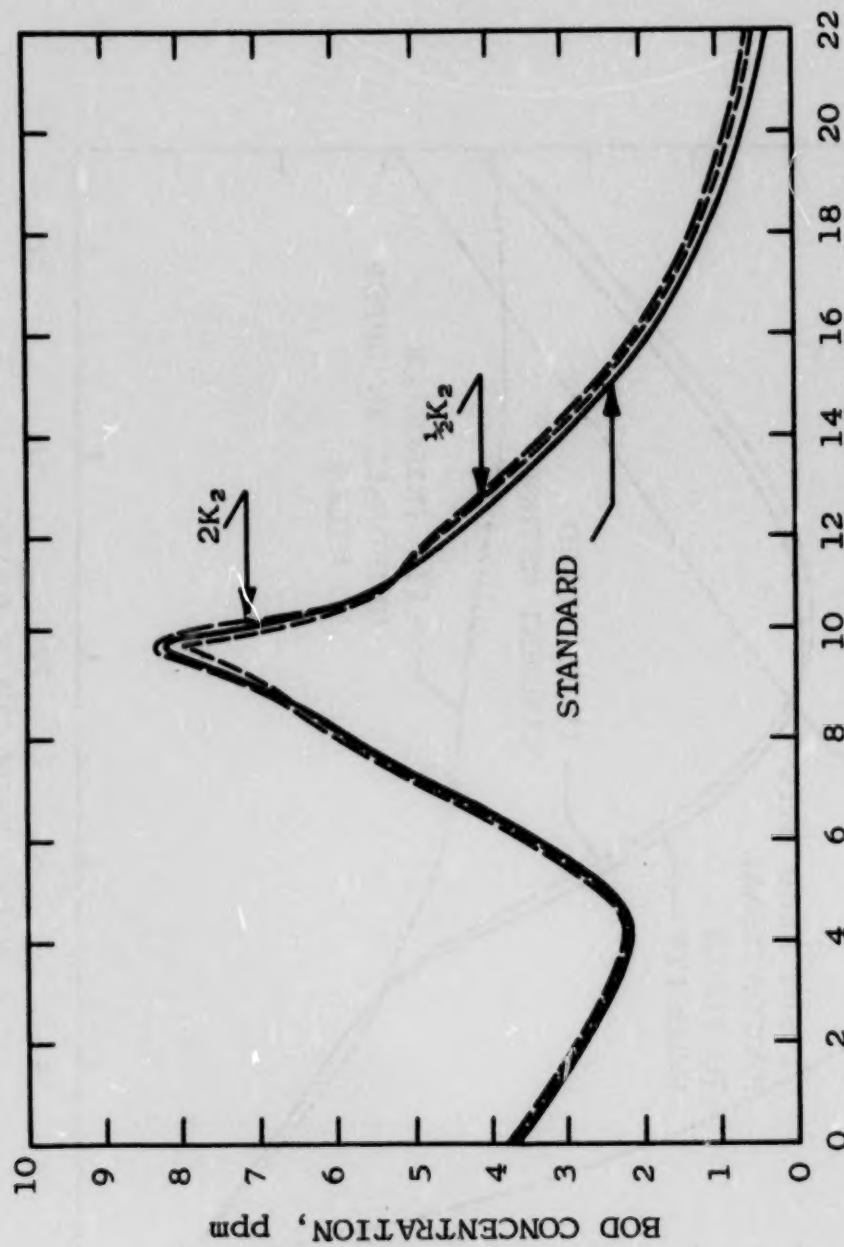


FIGURE 33 BOD PROFILES RESULTING FROM THREE LEVELS OF REAERATION RATE FOR THE POTOMAC ESTUARY

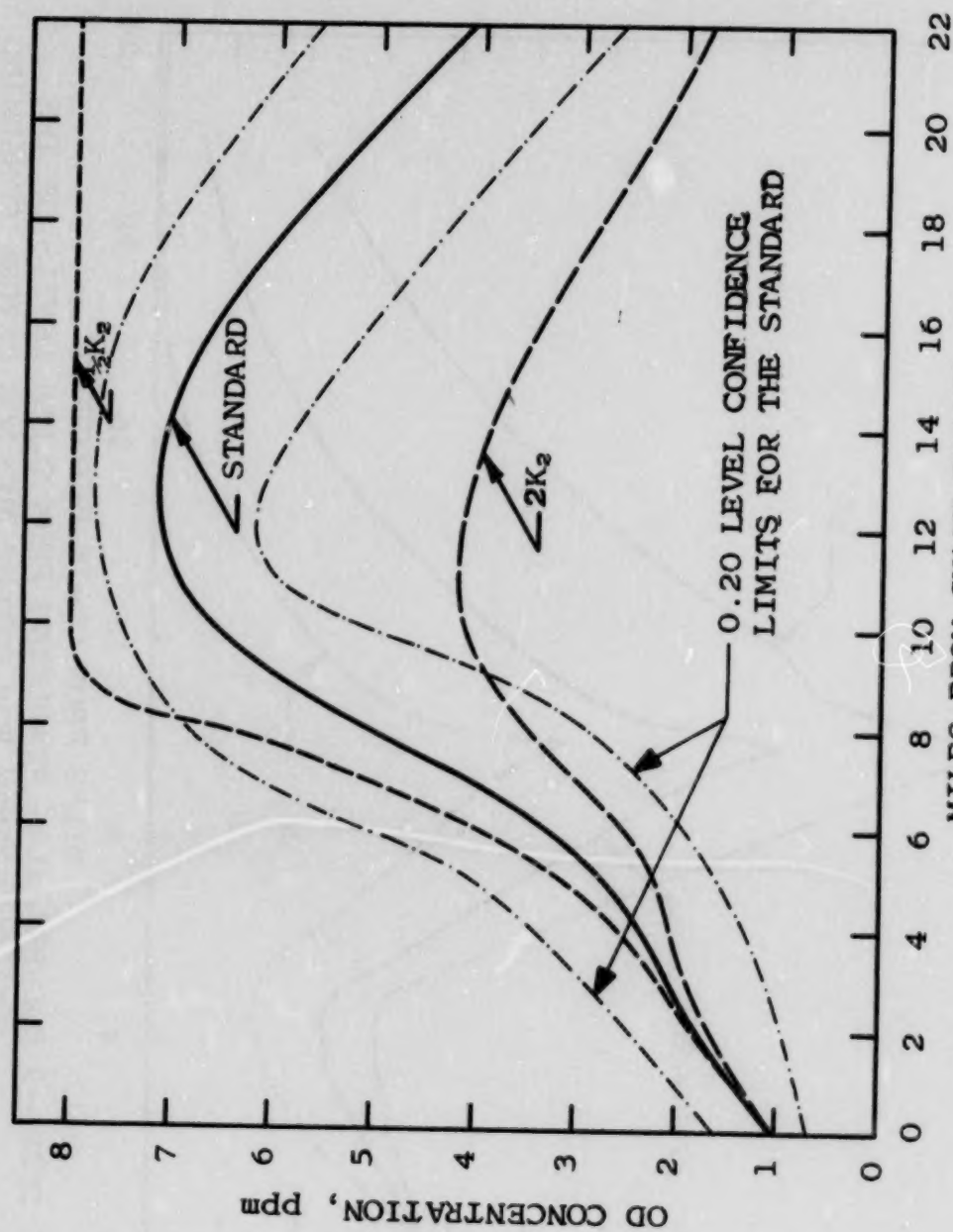


FIGURE 34 OD PROFILES RESULTING FROM THREE LEVELS OF REAERATION RATE CONSTANT FOR THE POTOMAC ESTUARY

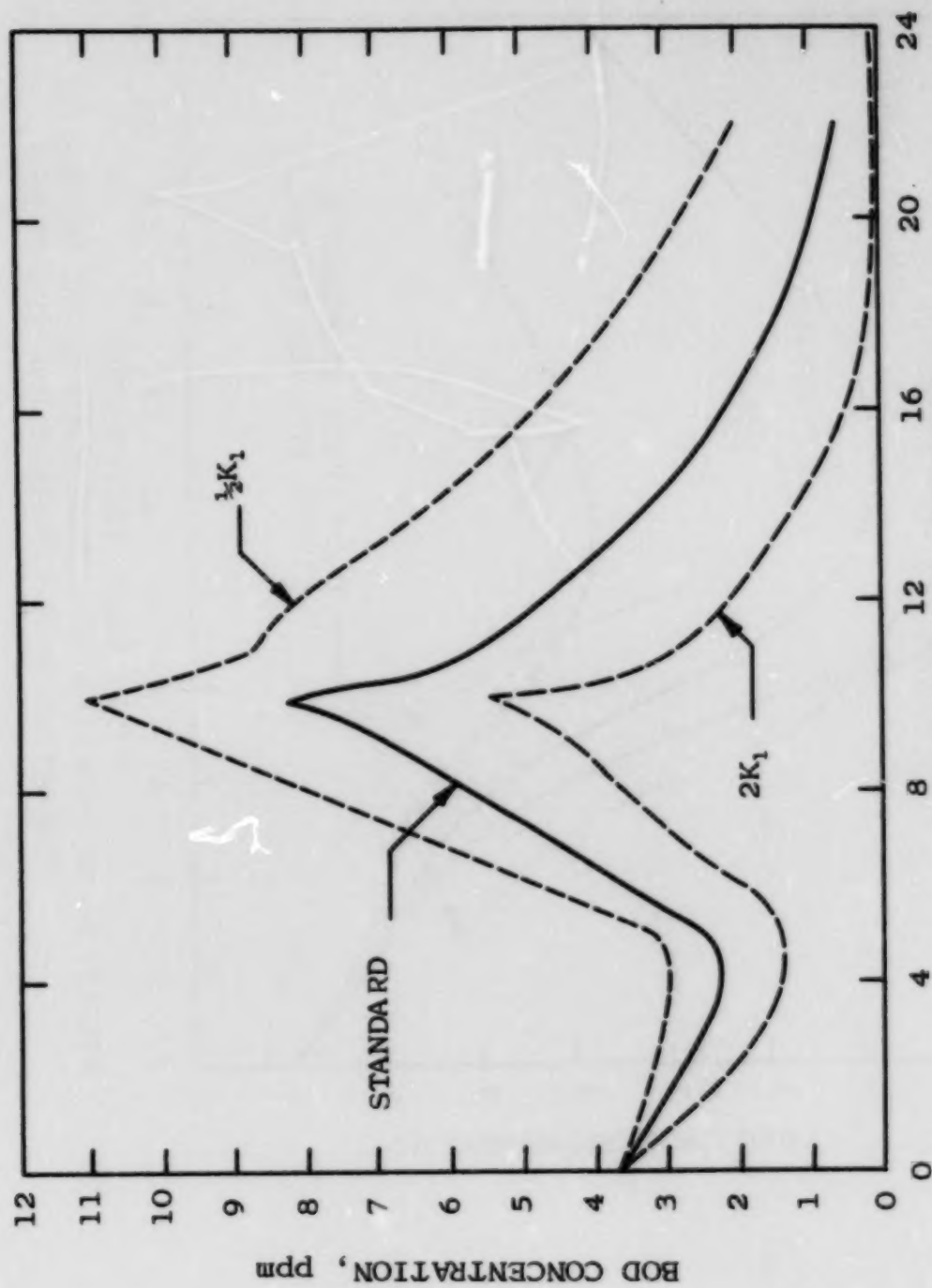


FIGURE 35 BOD PROFILES RESULTING FROM THREE LEVELS OF THE RATE CONSTANTS FOR OXYGEN AND NON-OXYGEN CONSUMING PROCESSES FOR THE POTOMAC ESTUARY

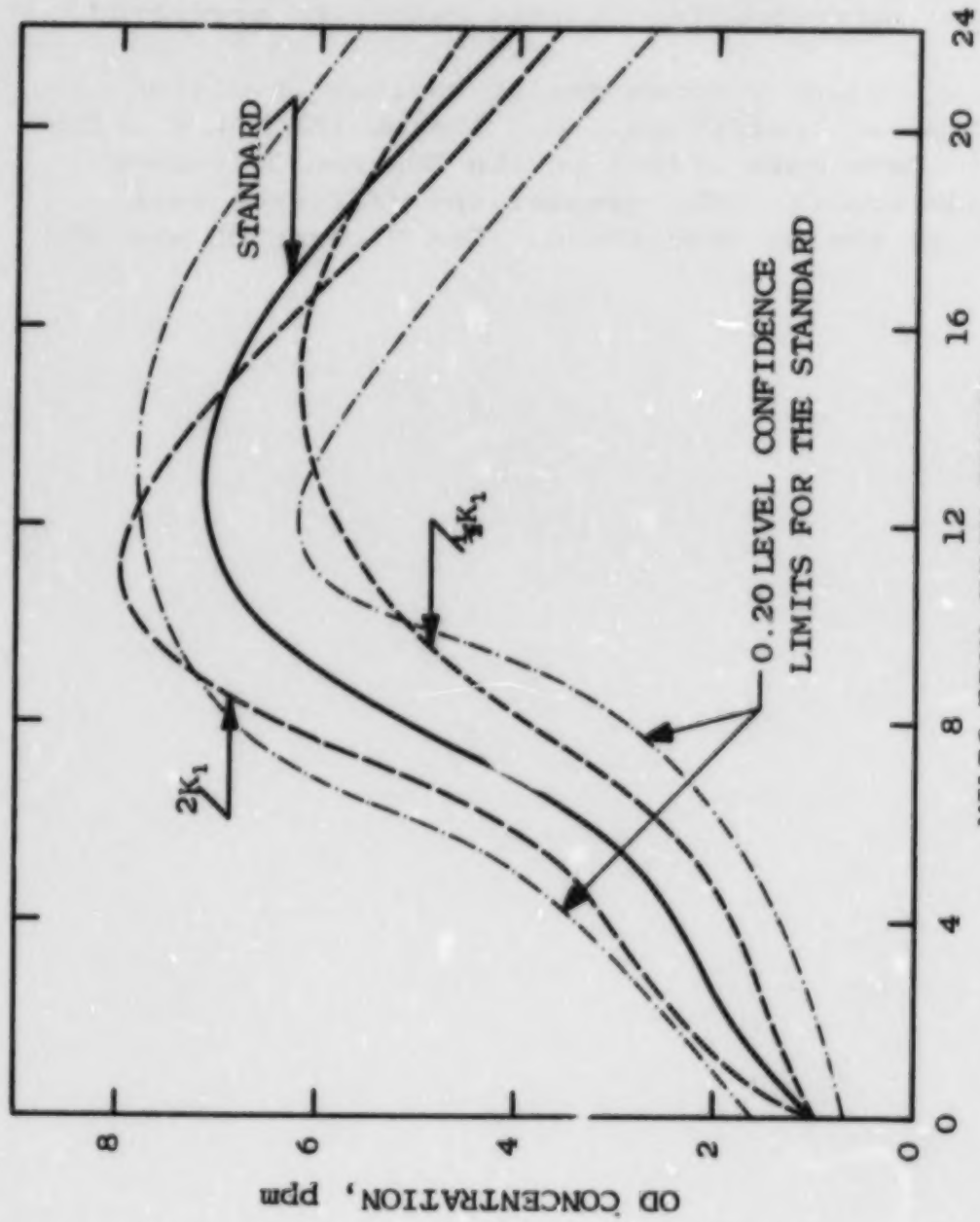


FIGURE 36 OD PROFILES RESULTING FROM THREE LEVELS OF THE RATE CONSTANT FOR BIOLOGICAL UTILIZATION OF BOD FOR THE POTOMAC ESTUARY

The effect of various STP output rates can be seen by inspecting Figures 37 and 38. The OD curve indicates that anaerobic conditions would be reached with feed rates at twice their normal level. Once again the exact BOD curve corresponding to this cannot be predicted.

The last group studied was of various levels of the diffusion coefficient, E . Increasing the E value seems to have more effect on the BOD and OD curves than reducing it. The greater the diffusion rate, the better the OD conditions. See Figures 39 and 40.

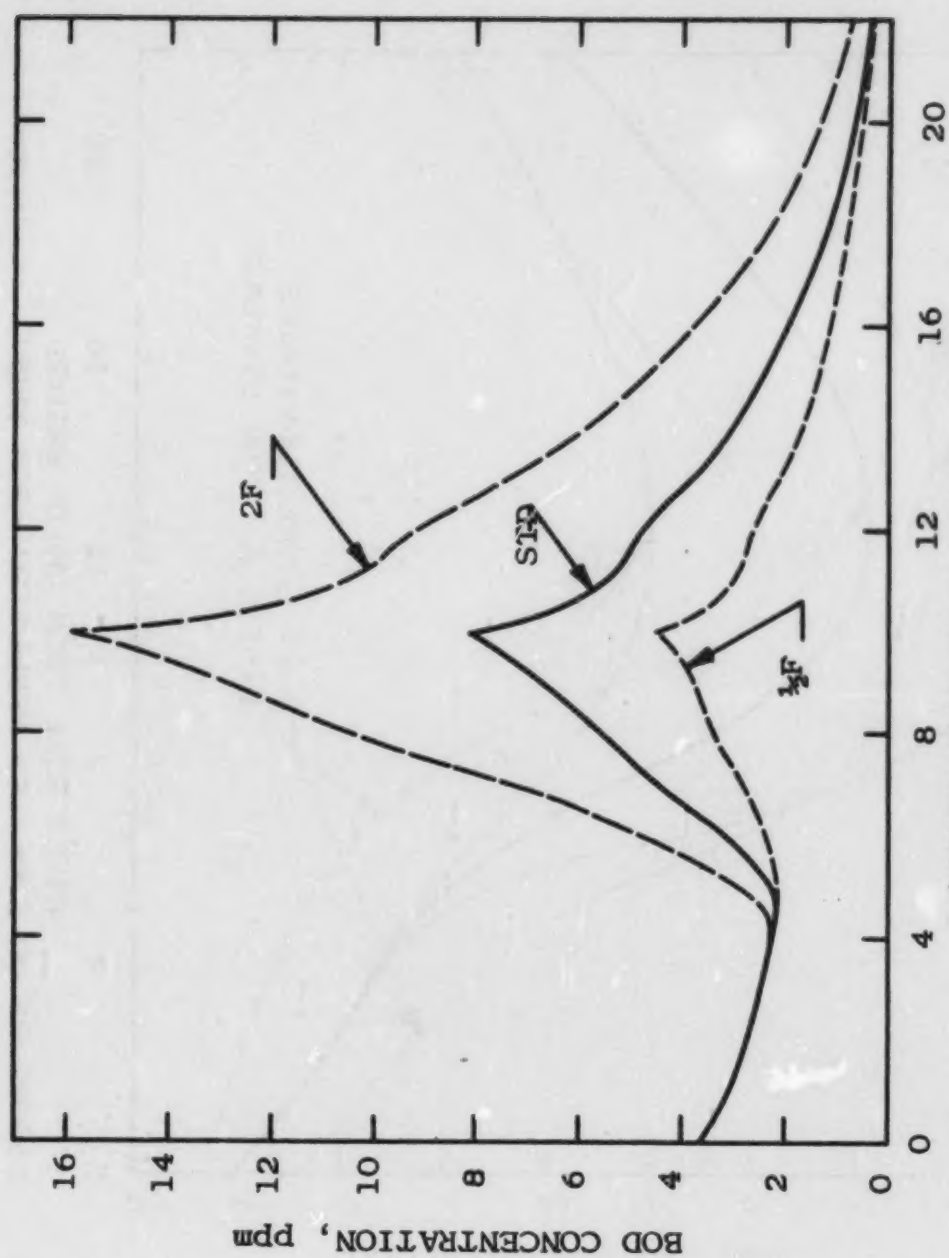


FIGURE 37 BOD PROFILES RESULTING FROM THREE POLLUTION
INPUT RATES FOR THE POTOMAC ESTUARY
RIVER MILE FROM CHAIN BRIDGE

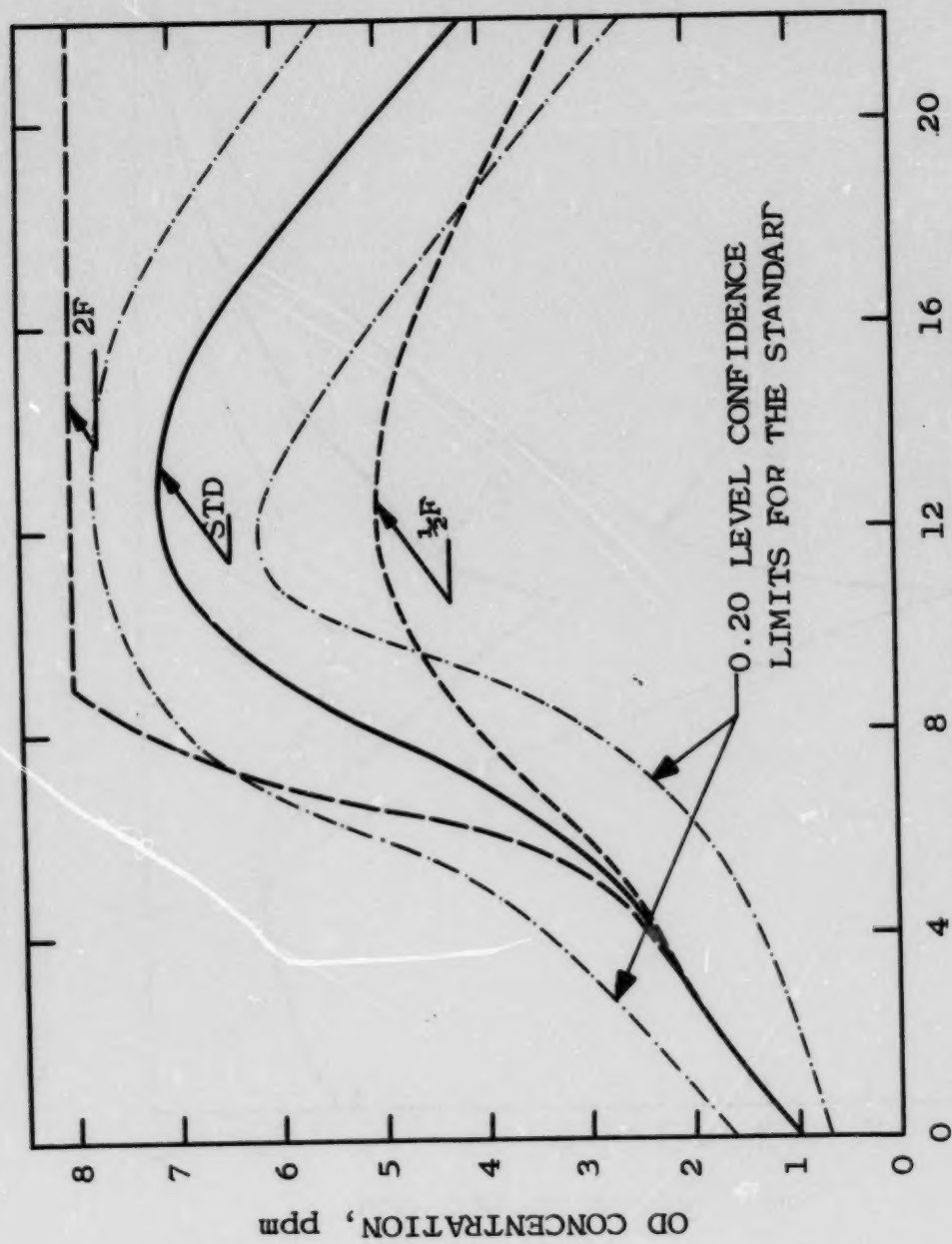


FIGURE 38 OD PROFILES RESULTING FROM THREE POLLUTION INPUT RATES FOR THE POTOMAC ESTUARY RIVER MILE FROM CHAIN BRIDGE

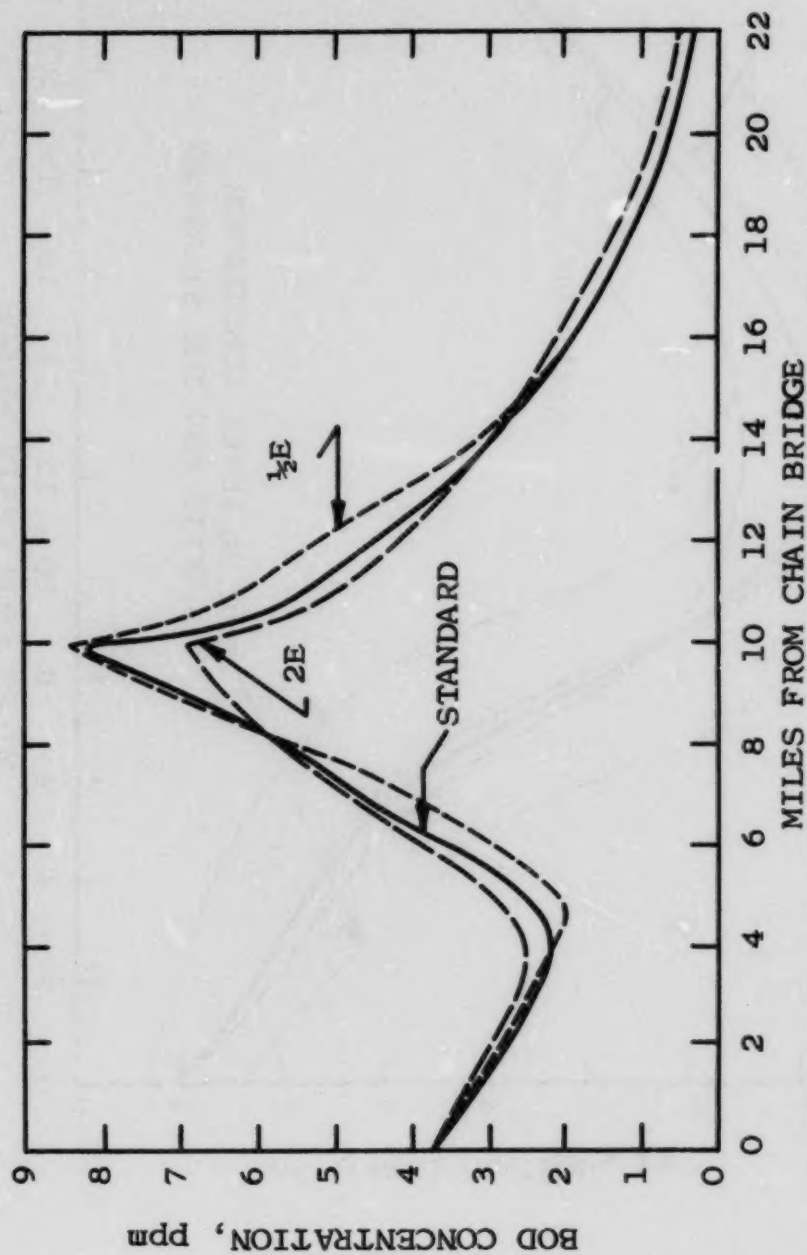


FIGURE 39 BOD PROFILES RESULTING FROM THREE LEVELS OF DIFFUSION RATE CONSTANT FOR THE POTOMAC ESTUARY

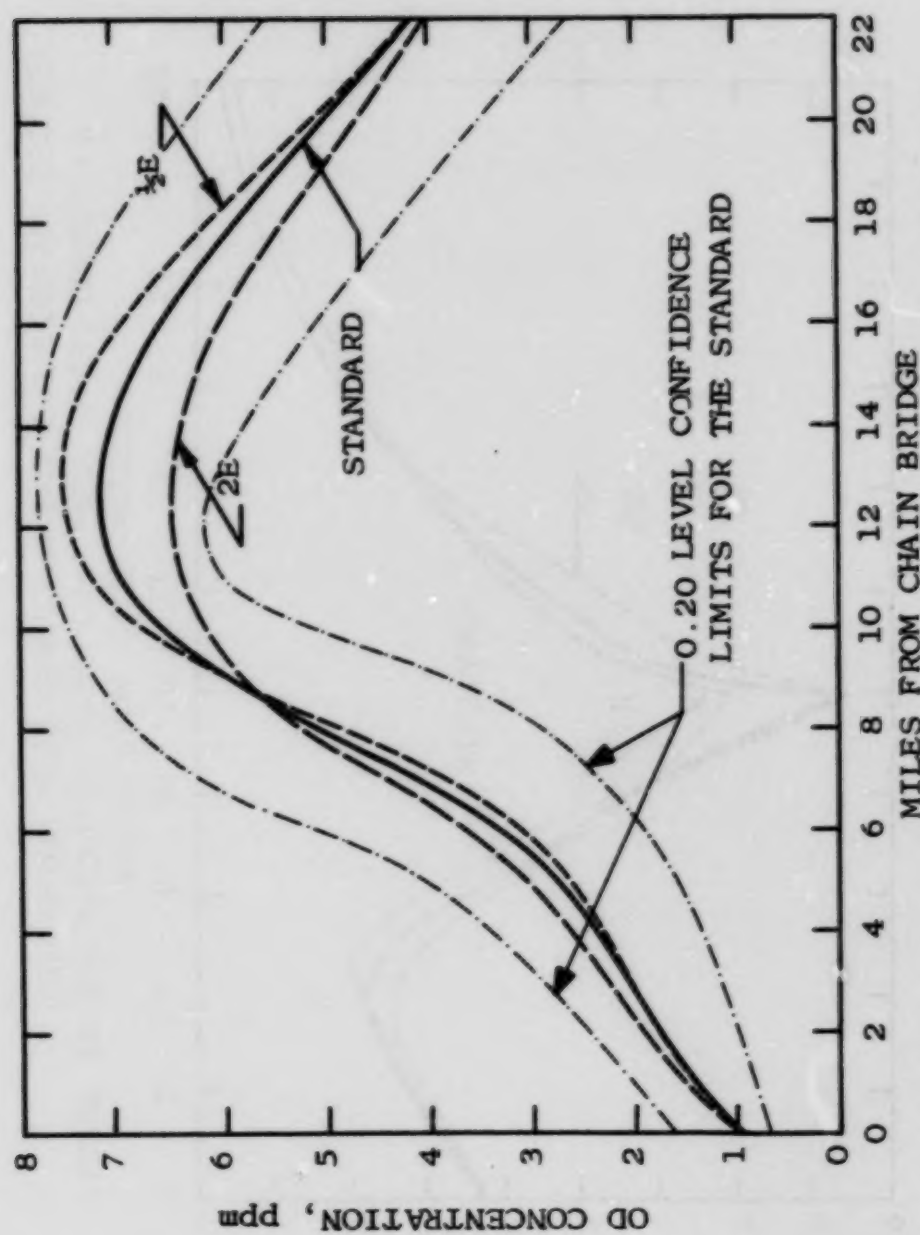


FIGURE 40 OD PROFILES RESULTING FROM THREE LEVELS OF
DIFFUSION RATE CONSTANT FOR THE POTOMAC ESTUARY

A METHOD FOR PREDICTING Δ

As was mentioned in the INTRODUCTION, this task had many subprojects which were necessary in order to determine the nature of Δ . Several of these subprojects are discussed in the INTRODUCTION. Here we will give the details of two of these subprojects.

CONTINUOUS STATE SPACE

The stochastic models for streams and estuaries considered by Thayer and Krutchkoff, and Custer and Krutchkoff, and the model considered in this report were derived by considering discrete processes and then letting $\delta t \rightarrow 0$ in order to obtain continuous time solutions. Thayer and Krutchkoff obtained a set of differential-difference equations and then used the probability generating function technique to obtain a solution to these equations. Custer and Krutchkoff and the model derived in this report obtain solutions to a set of difference equations and then use continuous approximations to estimate the BOD and OD concentrations for the estuary. These approaches are correct, although the models could have been derived by initially considering the process as continuous. Here we present a continuous space derivation and then use the simple model of Thayer and Krutchkoff to illustrate the similarities and differences in the two approaches.

Let $X(t)$ represent the pollution concentration at time t . Also let $X(t)$ and $X(r)$ take on values x and y at times t and r , respectively. We will treat the pollution model as a continuous Markov process. More specifically, we assume that there exists a density $f(x, t | y, r)$ such that

$$\Pr[X \leq x \text{ at time } = t | X = y \text{ at time } = r] = \int_{-\infty}^x f(z, t | y, r) dz. \quad (r < t). \quad (201)$$

This is the probability that the pollution is x or less at time t given that it was exactly equal to y at some previous time r

The assumption of the Markov property means that given the present state of the system the future behavior of the system is independent of any past behavior. It can also be shown that f must satisfy

$$f(x, t | y, r) = \int_{-\infty}^{\infty} f(x, t | z, s) f(z, s | y, r) dz$$

(202)

$r < s < t.$

The objective is to find $f(x, t | y, r)$ for specified initial conditions. The forward and backward Kolmogorov equations (see [6]) describe the density with equation (202) used to obtain them. For the backward equation the three points $r-h < r < t$ on the time axis are considered. Two limiting functions are also assumed to exist; namely

$$a(y, r) = \lim_{h \rightarrow 0} \frac{1}{h} \int_{-\infty}^{\infty} (x-y) f(x, r | y, r-h) dx$$

(203)

and

$$b(y, r) = \lim_{h \rightarrow 0} \frac{1}{h^2} \int_{-\infty}^{\infty} (x-y)^2 f(x, r | y, r-h) dx$$

(204)

where $a(y, r)$ and $b(y, r)$ are respectively called the infinitesimal mean and variance of the process. They are the expected jump and the variance of this jump in pollution from state y to state x . For the forward equation the three points $r < t < t+h$ are considered along with $a(x, t)$ and $b(x, t)$ which are defined in a similar manner. Using these definitions the Kolmogorov equations are given as, the backward equation:

$$\begin{aligned} \frac{-\partial f(x, t | y, r)}{\partial r} = & a(y, r) \frac{\partial f(x, t | y, r)}{\partial y} \\ & + \frac{1}{2} b(y, r) \frac{\partial^2 f(x, t | y, r)}{\partial y^2} \end{aligned}$$

(205)

and the forward equation:

$$\frac{\partial f(x,t|y,r)}{\partial t} = \frac{-\partial}{\partial x} [a(x,t)f(x,t|y,r)] + \frac{1}{2} \frac{\partial^2}{\partial x^2} [b(x,t)f(x,t|y,r)] \quad (206)$$

Either equation may be used to find the density f . A solution to the forward equation will provide f for fixed initial conditions; namely y fixed and r fixed. Since, by assumption the process is homogeneous over time, i.e. the transition probabilities depend only on the time difference $t-r$, we can write

$$\begin{aligned} a(y,r) &= a(y) & b(y,r) &= b(y) \\ a(x,t) &= a(x) & b(x,t) &= a(x) \end{aligned} \quad (207)$$

Appropriate substitutions can be made in equations (205) and (206).

THE MEAN AND VARIANCE FOR THE CONTINUOUS MARKOV PROCESS

Now assume that $a(x)$ and $b(x)$ are functions such that the forward equation can be written

$$\frac{\partial f}{\partial t} = a_0 f + (a_1 + a_2 x) \frac{\partial f}{\partial x} + (a_3 + a_4 x) \frac{\partial^2 f}{\partial x^2}. \quad (208)$$

Such a form will arise whenever $a(x)$ and $b(x)$ are linear. Rather than going immediately into the assumptions about K_1, K_2, K_3, L, D_0 , and Δ of the pollution problem, let us first solve the more general equation above. Thayer's assumptions, as we shall see, simply assign specific values (depending on the K 's) to the constants in the general equation above.

Finding f from the equation above is an exceptionally difficult task. The first two moments, however, are not too difficult to obtain. Let us then find the

mean and variance of $X(t)$. Let f be a density function of the random variable X which also involves another mathematical variable t . Suppose X is described by the partial differential equation

$$\frac{\partial f}{\partial t} = a_0 f + (a_1 + a_2 x) \frac{\partial f}{\partial x} + (a_3 + a_4 x) \frac{\partial^2 f}{\partial x^2}. \quad (209)$$

We wish to find the first two moments of X , namely $\mu_X(t)$ and $\sigma_X^2(t)$.

Let us multiply the whole equation (209) by x and integrate over the range $(0, \infty)$.

$$\begin{aligned} \int_0^\infty x \frac{\partial f}{\partial t} dx &= a_0 \int_0^\infty x f dx + \int_0^\infty (a_1 + a_2 x) x \frac{\partial f}{\partial x} dx \\ &+ \int_0^\infty (a_3 + a_4 x) x \frac{\partial^2 f}{\partial x^2} dx. \end{aligned} \quad (210)$$

Equation (210) can be written

$$\begin{aligned} d\mu_X(t) &= a_0 \mu_X(t) + (a_1 + a_2 x) x f \Big|_0^\infty \\ &- \int_0^\infty (a_1 + 2a_2 x) f dx + (a_3 + a_4 x) x \frac{\partial f}{\partial x} \Big|_0^\infty - \int_0^\infty (a_3 + 2a_4 x) \frac{\partial f}{\partial x} dx. \end{aligned} \quad (211)$$

by using the integration by parts. Therefore

$$\begin{aligned} \frac{d\mu_X(t)}{dt} &= a_0 \mu_X(t) - a_1 - 2a_2 \mu_X(t) \\ &- (a_3 + 2a_4 x) f \Big|_0^\infty + \int_0^\infty (2a_4) f dx \\ &= a_0 \mu_X(t) - a_1 - 2a_2 \mu_X(t) + 2a_4 \\ &= (a_0 - 2a_2) \mu_X(t) + 2a_4 - a_1. \end{aligned} \quad (212)$$

This is an ordinary differential equation for $\mu_x(t)$. From the theory of ordinary differential equations any linear first order equation of the form

$$\frac{dz}{ds} + P(s)z = Q(s) \quad (213)$$

has solution

$$z(s) = e^{-\int^s P(y) dy} \int^s Q(y) e^{\int^s P(y) dy} dy + ce^{-\int^s P(y) dy} \quad (214)$$

Application of formula (214) to equation (212) provides

$$\begin{aligned} \mu_x(t) &= e^{+(a_0-2a_2)t} \int_0^t (2a_4-a_1) e^{-(a_0-2a_2)t} dt \\ &+ ce^{+(a_0-2a_2)t} \\ &= e^{+(a_0-2a_2)t} \frac{(2a_4-a_1)}{-(a_0-2a_2)} [e^{-(a_0-2a_2)t} - 1] \\ &+ ce^{+(a_0-2a_2)t} \\ &= \frac{(2a_4-a_1)}{(2a_2-a_0)} [1 - e^{(a_0-2a_2)t}] \\ &+ ce^{(a_0-2a_2)t} \quad (215) \end{aligned}$$

Now letting $\eta_x(t) = E\{x^2 | t\}$, multiplying equation (209) by x^2 and integrating over the range $(0, \infty)$ one obtains

$$\begin{aligned} \int_0^\infty x^2 \frac{\partial f}{\partial t} dx &= a_0 \int_0^\infty x^2 f dx + \int_0^\infty (a_1 + a_2 x) x^2 \frac{\partial f}{\partial x} dx \\ &+ \int_0^\infty (a_3 + a_4 x) x^2 \frac{\partial^2 f}{\partial x^2} dx \quad (216) \end{aligned}$$

or

$$\begin{aligned}
 \frac{d\eta_x(t)}{dt} &= a_0 \eta_x(t) + (a_1 + a_2 x) x^2 f \Big|_0^\infty \\
 - \int_0^\infty (2a_1 x + 3a_2 x^2) f dx + (a_3 + a_4 x) x^2 \frac{\partial f}{\partial x} - \int_0^\infty (2a_3 x + 3a_4 x^2) \frac{\partial f}{\partial x} dx \\
 &= a_0 \eta_x(t) - 2a_1 \mu_x(t) - 3a_2 \eta_x(t) \\
 - (2a_3 x + 3a_4 x^2) f \Big|_0^\infty + \int_0^\infty (2a_3 + 6a_4 x) f dx \\
 &= (a_0 - 3a_2) \eta_x(t) - 2a_1 \mu_x(t) \\
 + 6a_4 \mu_x(t) + 2a_3. \quad (217)
 \end{aligned}$$

Applying formula (214) to (217) above,

$$\begin{aligned}
 \eta_x(t) &= e^{(a_0 - 3a_2)t} \int_0^t [6a_4 - 2a_1] \mu_x(t) dt + k e^{(a_0 - 3a_2)t} \\
 + 2a_3] e^{(a_0 - 3a_2)t}. \quad (218)
 \end{aligned}$$

If the constants are specified, $\mu_x(t)$ can easily be determined. After finding $\mu_x(t)$, $\sigma^2_x(t)$ can easily be evaluated by putting $\mu_x(t)$ in (218) and then setting

$$\sigma^2_x(t) = \eta_x^2(t) - \mu_x^2(t). \quad (219)$$

COMPARING WITH THAYER AND KRUTCHKOFF

Thayer and Krutchkoff assumed that pollution entered the streams in discrete increments of size Δ and the factors which cause the concentration of pollution x to change are as given in the INTRODUCTION. Directly from these factors one can obtain that

$$E(\text{jump}) = E(i\Delta) = [L_a - (K_1 + K_3)x]h + o(h) \quad (220)$$

and

$$\text{VAR}(\text{jump}) = \text{VAR}(i\Delta) = \Delta [L_a + (K_1 + K_3)x]h$$

$$+ o(h^2) \quad (221)$$

where i is the number of unit jumps in time period h . From the general results on continuous stochastic processes [6], it is reasonable to assume that the infinitesimal mean $a(x)$ and variance $b(x)$ given previously are proportional to the pollution concentration. Thus, if the mean and variance of the jump are given appropriately by (220) and (221) then $a(x)$ and $b(x)$ become

$$a(x) = L_a - (K_1 + K_3)x \quad (222)$$

$$b(x) = [L_a + (K_1 + K_3)x]\Delta. \quad (223)$$

The parameter Δ considered in this way is not a mechanism for discretizing pollution concentrations, but is merely a scale factor in the basic variance of the problem. If Δ were large, x could undergo wide swings in a time increment h ; if small, x would remain fairly stable. We do not need to consider pollution as coming in Δ -size increments. Δ is a characteristic of the stream or estuary and of the biological process.

Let us now write the forward Kolomogorov equation with $a(x)$ and $b(x)$ given by equations (222) and (223). This becomes

$$\frac{\partial f}{\partial t} = \frac{-\partial}{\partial x} [a(x)f] + \frac{1}{2} \frac{\partial^2}{\partial x^2} [b(x)f]. \quad (224)$$

Thus, as a continuous analog to the Thayer and Krutchkoff assumption

$$\begin{aligned} \frac{\partial f}{\partial t} &= \frac{-\partial}{\partial x} [(L_a - (K_1 + K_3)x)f] + \frac{1}{2} \frac{\partial^2}{\partial x^2} [\Delta(L_a + \\ & (K_1 + K_3)x)f] \\ &= -L_a \frac{\partial f}{\partial x} + (K_1 + K_3)x \frac{\partial f}{\partial x} + (K_1 + K_3)f \\ &+ \frac{\Delta}{2} \left\{ L_a \frac{\partial^2 f}{\partial x^2} + (K_1 + K_3) \frac{\partial f}{\partial x} + (K_1 + K_3) \frac{\partial f}{\partial x} + (K_1 + K_3)x \frac{\partial^2 f}{\partial x^2} \right\} \end{aligned}$$

$$\begin{aligned}
&= (-L_2 + (K_1 + K_3) \Delta + (K_1 + K_3) x) \frac{\partial f}{\partial x} + \frac{\Delta}{2} (L_2 \\
&+ (K_1 + K_3) x) \frac{\partial^2 f}{\partial x^2} + (K_1 + K_3) F.
\end{aligned} \tag{225}$$

Thus,

$$\begin{aligned}
\mu_x(t) &= \frac{L_2}{K_1 + K_3} [1 - e^{-(K_1 + K_3)t}] \\
&+ ce^{-(K_1 + K_3)t}
\end{aligned} \tag{226}$$

and

$$\begin{aligned}
\eta_x(t) &= e^{-2(K_1 + K_3)t} \int_0^t \{ [3(K_1 + K_3) \Delta \\
&- 2(K_1 + K_3) \Delta + 2L_2] \mu_x(t) + L_2 \Delta \} e^{+2(K_1 + K_3)t} dt + Ke^{-2(K_1 + K_3)t} \\
&= e^{-2(K_1 + K_3)t} \{ [(K_1 + K_3) \Delta + 2L_2]
\end{aligned}$$

$$\begin{aligned}
&\int_0^t \mu_x(t) e^{2(K_1 + K_3)t} dt + L_2 \int_0^t e^{2(K_1 + K_3)t} dt + K \} \\
&= e^{-2(K_1 + K_3)t} \{ [(K_1 + K_3) \Delta + 2L_2]
\end{aligned}$$

$$\int_0^t e^{2(K_1 + K_3)t} \left\{ \frac{L_2}{K_1 + K_3} [1 - e^{-(K_1 + K_3)t}] + ce^{-(K_1 + K_3)t} \right\} dt$$

$$+ \frac{L_2 \Delta}{2(K_1 + K_3)} [e^{2(K_1 + K_3)t} - 1] + K \}$$

$$= e^{-2(K_1 + K_3)t} \left[[(K_1 + K_3) \Delta + 2L_2]
\right.$$

$$\left. \left\{ \int_0^t \frac{L_2}{K_1 + K_3} [e^{2(K_1 + K_3)t} - e^{(K_1 + K_3)t}] dt + \int_0^t ce^{(K_1 + K_3)t} dt \right\} \right]$$

$$+ \frac{L_a \Delta}{2(K_1 + K_3)} [e^{2(K_1 + K_3)t} - 1] + K]$$

$$= e^{-2(K_1 + K_3)t} \left[[(K_1 + K_3)\Delta + 2L_a] \right]$$

$$\left\{ \frac{L_a}{K_1 + K_3} \left[\frac{e^{2(K_1 + K_3)t}}{2(K_1 + K_3)} - \frac{e^{(K_1 + K_3)t}}{(K_1 + K_3)} \right] \right\}_0^t + \frac{c}{K_1 + K_3} e^{(K_1 + K_3)t} \Big|_0^t \Big\}$$

$$+ \frac{L_a \Delta}{2(K_1 + K_3)} [e^{2(K_1 + K_3)t} - 1] + K]$$

$$= e^{-2(K_1 + K_3)t} \left[[(K_1 + K_3)\Delta + 2L_a] \right]$$

$$\left\{ \frac{L_a}{(K_1 + K_3)^2} \left\{ \frac{e^{2(K_1 + K_3)t}}{2} - e^{(K_1 + K_3)t} + \frac{1}{2} \right\} + \frac{c}{K_1 + K_3} [e^{(K_1 + K_3)t} - 1] \right\}$$

$$+ \frac{L_a \Delta}{2(K_1 + K_3)} [e^{2(K_1 + K_3)t} - 1] + K]$$

$$= e^{-2(K_1 + K_3)t} \left\{ \frac{[(K_1 + K_3)\Delta + 2L_a] L_a}{2(K_1 + K_3)^2} \right.$$

$$\left. [e^{(K_1 + K_3)t} - 1]^2 + \frac{[(K_1 + K_3)\Delta + 2L_a] c}{K_1 + K_3} [e^{(K_1 + K_3)t} - 1] + \frac{L_a \Delta}{2(K_1 + K_3)} \right\}$$

$$[1 - e^{-2(K_1 + K_3)t}] + K e^{-(K_1 + K_3)t}$$

$$= \frac{[(K_1 + K_3)\Delta + 2L_a] L_a}{2(K_1 + K_3)^2} [1 - e^{-(K_1 + K_3)t}]^2$$

$$+ \frac{[(K_1 + K_3)\Delta + 2L_a] c}{K_1 + K_3} e^{-(K_1 + K_3)t} [1 - e^{(K_1 + K_3)t}] + \frac{L_a \Delta}{2(K_1 + K_3)}$$

$$[1 - e^{-2(K_1 + K_3)t}] + K e^{-2(K_1 + K_3)t} \quad (227)$$

and

$$\begin{aligned} \sigma_x^2(t) &= \eta_x(t) - \mu_x^2(t) \\ &= \eta_x(t) - \frac{L_a^2}{(K_1 + K_3)^2} [1 - e^{-(K_1 + K_3)t}]^2 \\ &\quad - c^2 e^{-(K_1 + K_3)t} - \frac{2cL_a}{K_1 + K_3} e^{-(K_1 + K_3)t} [1 - e^{-(K_1 + K_3)t}] \\ &\quad - \frac{L_a \Delta}{2(K_1 + K_3)} [1 - e^{-(K_1 + K_3)t}]^2 \\ &\quad + c\Delta e^{-(K_1 + K_3)t} [1 - e^{-(K_1 + K_3)t}] + \frac{L_a \Delta}{2(K_1 + K_3)} [1 - e^{-2(K_1 + K_3)t}] \\ &\quad + (K - c^2) e^{-2(K_1 + K_3)t} \\ &= \Delta \left[\frac{L_a}{2(K_1 + K_3)} [1 - e^{-(K_1 + K_3)t}]^2 \right. \\ &\quad \left. + c e^{-(K_1 + K_3)t} [1 - e^{-(K_1 + K_3)t}] + \frac{L_a}{2(K_1 + K_3)} [1 - e^{-2(K_1 + K_3)t}] \right] \\ &\quad + (K - c^2) e^{-2(K_1 + K_3)t} \end{aligned} \quad (228)$$

where

$$\begin{aligned} \mu_x(0) &= c \\ \text{and } \sigma_x^2(0) &= K - c^2. \end{aligned}$$

Now suppose that $c = L_a$ and $\sigma_x^2(0) = 0$, then

$$\mu_x(t) = \frac{L_a}{K_1 + K_3} (1 - e^{-(K_1 + K_3)t}) + L_a e^{-(K_1 + K_3)t} \quad (229)$$

and

$$\sigma_x^2(t) = \Delta \left\{ \frac{L_a}{2(K_1 + K_3)} - \frac{L_a e^{-(K_1 + K_3)t}}{(K_1 + K_3)} \right\}$$

$$\begin{aligned}
& + \frac{L_a}{2(K_1 + K_3)} e^{-2(K_1 + K_3)t} + L_a e^{-(K_1 + K_3)t} - L_a e^{-2(K_1 + K_3)t} \\
& + \frac{L_a}{2(K_1 + K_3)} - \frac{L_a}{2(K_1 + K_3)} e^{-2(K_1 + K_3)t} \Bigg\} \\
& = \Delta \left(L_a e^{-(K_1 + K_3)t} + \frac{L_a}{K_1 + K_3} \right) \\
& \left(1 - e^{-(K_1 + K_3)t} \right). \tag{230}
\end{aligned}$$

The mean (229) and variance (230) are identical to the mean and variance for the amount of pollution given by the corresponding equations in the Thayer and Krutchkoff model. Thus, we have shown that one obtains identical means and variance for the amount of pollution using either a continuous approach or a discrete approach and then letting $h \rightarrow 0$. The fundamental difference between the approaches is the interpretation of Δ . Using the continuous derivation, Δ is given a much more meaningful interpretation with respect to the actual physical situation.

THE TWO STAGE METHOD FOR PREDICTING Δ

The first stage of the TWO STAGE METHOD takes all the available data and checks to see how to factor the variables to obtain a reasonable within factor estimate of Δ . These factors and the estimates of Δ are then put into a standard regression program to obtain the best least squares fit. This is the second stage.

If used with a good deal of insight, as to which factors are important, the first stage will make optional use of the data available. If used without this, the first stage program will still do a reasonable job in deciding which factors and how many levels are required for a reasonable regression equation.

Since the second stage program is any standard

regression program we will only discuss the FIRST STAGE PROGRAM here.

THE FIRST STAGE PROGRAM

The FIRST STAGE PROGRAM FOR PREDICTING DELTA was written so that more efficient sets of deltas can be obtained in order to form an accurate regression type prediction model. This program will handle up to 6 variables, one of which will be used to calculate the deltas. The variable will be referred to as the dependent variable. The other variables will be referred to either as independent variables or as factors. These variables may be punched anywhere on the data card because no standard data input format is used. The program sorts the data into cells according to the number of levels placed on each factor and to the range values or cut-off points for each of these levels.

As an example of this, suppose that there are 3 variables, the first being the dependent variable (e.g. OD), the second variable factor 1 (e.g. temperature); and the third variable, factor 2 (e.g. BOD concentration). One may, for example, first decide to try 3 levels on factor 1 and 4 levels on factor 2. The range values or cut-off points for the levels of factor 1 might be 65.0 and 80.0, and for factor 2 8.0, 12.0, and 16.0. Thus, if an observation on factor 1 is less than or equal to 65.0, it will be classified as level 1 of factor 1. If it is greater than 80.0, it then falls in level 3. Thus, if factor 1 was 55.6 and factor 2 was 16.5, then this observation would be level 1 of factor 1 and level 3 of factor 2 and would thus fall in cell (1,3).

The programmer can decide on the number of levels he would like to start with for each factor and also the range points. The program will sort the data according to these levels and will store these facts in the cell corresponding to these factor levels. The program then prints out a histogram showing the number of cells that had 0 observations in it, 1

observation in it and on up to the number of cells with 19 observations in each. This histogram is truncated at 20 and thus if a cell has 20 or more observations in it, these cells are all considered as having 20 observations by the histogram. This histogram is made first over all levels of all factors. It is then broken down for each factor at each of its levels. For an example of one of these histograms see the sample output in the appendix. From runs like this the programmer can change his range values and number of levels in an attempt to have enough observations in most cells to compute accurate delta values. If desired, the program will just sort and print the histograms.

It is advisable to run the program several times to decide on the number of levels and the cut-off points for these levels, and then make one final run and have the deltas computed and punched. The programmer may also set the minimum number of observations that must be in a cell before a delta for that cell is calculated. This minimum must be at least 2 since delta is a function of the variation within the cell. Therefore, to obtain an estimate of this variance, we need at least 2 observations. Obviously, we can get a much better estimate of the mean and the variance with more observations. The estimators used to calculate the sample average and sample variance are:

$$\bar{X}_n = \sum_{i=1}^n X_i \quad (231)$$

and

$$s^2 = \frac{1}{n-1} \sum_{i=1}^n (X_i - \bar{X}_n)^2 \quad (232)$$

where n is the number of observations in the particular cell in which we are calculating the delta and X_i refers to the value of the dependent variables for $i=1, 2, \dots, n$. Delta is then calculated as

$$\Delta = s^2 / \bar{X}_n \quad (233)$$

This is done for each cell for which the number of observations equals or exceeds the minimum number specified.

The level averages are computed for each factor at each level. This means that for all values of factor 1 that fall in level 1, the average value was computed. The average was computed for each level of each factor. Thus, if factor 1 has 4 levels then 4 level averages will be computed. When the Δ is computed, it is printed in the output and is punched on a data card in the following way:

1. The number of observations in the cell from which Δ was computed.
2. The value of Δ .
3. The level average for factor 1 for the level associated with cell for this Δ .
4. The level average for factor 2 for the level associated with cell for this Δ .
5. The level average for factor 3.

This continues for all factors.

If one requires the level numbers printed and punched instead of the level averages, the program can be easily modified. In the program listing at format number 59, appears eight lines with AVE on the right side of the printout (columns 75-77). Directly below these lines are comment cards which explain how to replace these cards with AVE, in order to have level numbers punched instead of level averages.

If the number of observations of the cell associated with levels L2, L3, L4, L5, L6 of factors 1 through 5 respectively, is less than the specified minimum, then the Δ is not computed and a card is not punched for this cell. The cell identification and number of elements in the cell is printed in the output along with the deltas and level numbers. It is printed in a different format and is easily distinguished from the cells that had deltas computed. The following format is used:

ICOUNT (1, L2, L3, L4, L5, L6) = n

where L2 is the level number for variable 2 or factor 1. If you had only 4 variables, when L5 and L6 would be 1's. The level of the first variable, the dependent variable, will always be 1. The number of observations in the cell is n. See the sample output in the appendix.

When we have the deltas calculated, we know from which cells no deltas were computed; and from the deltas that were computed, we know how many observations were used to compute this value. Ideally, we would like to have 5 or more observations in each cell and also approximately the same number of observations in each cell. This would give us approximately the same precision for each delta. Obviously this is not always possible. This program is an attempt to help to the investigator obtain this result.

There are several restrictions to this program, the first being that the dependent variable is considered in the program as variable number 1. It is not necessary to have Δ punched with the dependent variable as the first on the card, however, because the program re-orders the Δ variables as they are read. This way one can make one run with OD as the dependent variable and later with BOD as the dependent variable. Another restriction is in the number of levels the factors can have. One factor which must be renumbered as factor number 1 can have up to 10 levels. All other factors can have no more than 5 levels. Also, as previously stated, one can have only 5 factors and 1 dependent variable. In the order that the variables are read in, they are considered as variables 1, 2, ..., NVAR where NVAR is the number of variables ($NVAR \leq 6$). You next tell the program how to rearrange the variables so that the dependent variable will be variable 1; variable 2 will be factor 1 (if a factor has more than 5 levels it must be this one); and the other factors will be variables 3 through NVAR.

When working with esturial data it will pay to

use the tidal phase as a factor. Subroutine TIDAL may be used to have a tidal phase returned between 0.0 and 1.0. One might also need a program to change DO to OD, for the deltas should be computed from the variable OD.

Data control cards, which are read by the program, explain the incoming data to the program. The data control cards should be punched as indicated below.

<u>Card</u> <u>Number</u>	<u>Columns</u>	<u>Description</u>
1	10	the number of variables (including dependent variable) (NVAR $\leq$ 6)
	11-20	the number of data cards (put in the rightmost columns; i.e. if 100 data cards put the 1 in col. 18)
	30	the number of format cards ($\leq$ 2)
	40	put a 1 in this column if you desire the deltas computed and punched, if not leave blank
	44-45	the minimum number you desire in a cell before computing Δ

<u>Card</u> <u>Number</u>	<u>Columns</u>	<u>Description</u>
2		This card is used to rearrange the variables. As the variables are read in from the data cards, they will initially be called variables 1, 2, ..., NVAR in the order they are read in. The dependent variable must be rearranged to become the first variable. If any factor has more than 5 levels, it must be rearranged as variable number 2. No other factor may have more than 5 levels
	5	Put a K in this column if the kth variable is to be the dependent variable.
	10	Put an m in this column to make the mth variable read in as the 2nd variable

(i.e. the first factor).
15 Put an n in this column to make the
nth variable the 2nd factor.

.

.

continue for as many factors as
were read in.

(When we now refer to variable number i, we are
referring to the ith rearranged variable.)

3 5 the number of levels of factor 1
10 the number of levels of factor 2
15 the number of levels of factor 3

.

.

.

continue for as many factors as
you have (NVAR-1)

(If a factor is to be sorted into all values $>x$ and
all $\leq x$, then it will have 2 levels, and its one range
value will be x .)

4 consider for example that factor 1
has n levels ($n \leq 10$)
1-10 Put the upper range for level 1 of
factor 1 such that if the value is
less than or equal to this number,
it will be classified as level 1.
Note: This number must be a real
number not an integer, Example: 3.0,
not 3.
11-20 The upper range of level 2 of factor
1 such that if the value is less than
or equal to this number but greater
than the number in columns 1-10, it
will be classified as level 2.
21-30

<u>Card</u> <u>Number</u>	<u>Column</u>	<u>Description</u>
.	.	.
.	.	.
.	.	.
5		Continue to the (n-1)th level. This number gives the upper range on the (n-1)th level. All values greater than this (n-1)th range number will be classified as the nth level.
5		Do the same thing for factor 2, on a new card.
.		.
.		.
.		.
6		Continue this until you have given the range of all levels for all factors.
6		This card or cards indicates the format that will be used to read the variables from the data cards. The variables must be read in as real numbers, not as integers. Start in Column 1 with a left parenthesis, then use standard Fortran formatting, ending with a right parenthesis. Example: Suppose we have 4 variables with the decimal points punched in the cards with numbers in columns 6-10, 20-21, 30-41, and 76-77. With the (in col. 1 the card would look like (5x,F5.0,9x,F2.0,8x,F12.0,34x,F2.0). If you have integers on your data cards, such as sampling stations 1, 2, and 3, just read this integers as a real number with an F1.0 format.

Following these cards are the data cards.

PREDICTION EQUATION FOR THE OHIO

The first stage program for predicting Δ was first used on data from the Ohio River. The original variables were station number, time, temperature, DO, and BOD. A simple program was first written to change the DO variable to OD. OD was then used as the dependent variable and the others were used as factors 1, 2, 3, and 4. In our final run to compute the deltas, we used 7 levels for station number, 4 levels for time (2:15 pm was read in as 1400015), 2 levels for temperature, and 3 levels for BOD. We thus had a total of 168 cells to compute the deltas from. After sorting, there were 68 cells with less than two observations in them, so we had 100 deltas computed. The same thing was done again using BOD as the dependent variable and OD as a factor.

With the output of this program, we used the deltas as the dependent variable and the factor level averages as independent variables in a standard regression program. We used a multiple regression program from the Biomedical Computer Programs, BMD03R. Any standard regression program would work. The best regression fit was obtained using the model:

$$y = -0.1998 + 0.0823X_1 + 0.002X_2 + 0.0078X_3 - 0.0081X_4 - 0.0088X_1^2 + 0.00004X_2^2 \quad (234)$$

where

- y is Δ (OD)
- X_1 is the sampling station number
- X_2 is the time of day
- X_3 is the temperature
- X_4 is the BOD.

Only the regression coefficients for X_1 and X_1^2 were significantly different from zero when using a t test. These coefficients were significant at the 97% significance level. This indicates that the average value at each station is as good a representation of Δ

as can be expected from the type of data available. That is, Δ does not vary significantly (except from station to station) with any of the variables for which data was available.

PREDICTING Δ FOR THE POTOMAC

THE FIRST STAGE PROGRAM FOR PREDICTING Δ was also used on Potomac estuary data and the deltas were computed. The original variables were DO, time, station number, and temperature. The DO variable was changed to OD to be used as the dependent variable and using the subroutine TIDAL the tidal phase was computed using the date and the time of day. We used 10 levels on tidal phase, 4 levels on station number, 4 levels on time, and 2 levels on temperature. There were thus 320 cells of which 32 had fewer than 2 observations. The multiple linear regression program was then run using the deltas as the dependent variable and the factor level averages as the independent variables. The best regression fit was obtained using the following model:

$$y = 2.73054 - 0.07955X_1 - 0.51446X_2 + 0.02114X_3 - 0.02569X_4 + 0.11264X_2^2 - 0.00078X_3^2 \quad (235)$$

where

- y is Δ (OD)
- X_1 is the tidal phase
- X_2 is the station number
- X_3 is the time of day
- X_4 is the temperature.

All regression coefficients were significantly different from 0 at the 70% significance level, with the regression coefficients for X_3 and X_3^2 significant at the 80% level, X_4 at the 90% level, and X_2 and X_2^2 significant at the 99.9% level.

This indicates that in an estuary Δ is a function

of all the variables for which data was available. Equation (235) can now be used to determine the Δ value for any station at any point in the tidal phase at any time of day and any temperature. We would, however, suggest further verification of this procedure before using equation (235) for another estuary.

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GLOSSARY AND ABBREVIATIONS

A	matrix of equation coefficients
A or A(x,t)	cross sectional area
a(x,t) or a(x)	infinitesimal mean
BOD	biochemical oxygen demand
b(x,t) or b(x)	infinitesimal variance
c	concentration variable
$\bar{c}$	vector of average segment concentrations
C. I.	confidence intervals
D	oxygen variable
D _B or D _B (x,t)	benthic demand
D ₀	initial oxygen concentration
DO	dissolved oxygen
E or E(x,t)	diffusion coefficient
EF	BOD diffusion coefficient
EG	OD diffusion coefficient
E(Y)	mean value of Y
F	initial BOD concentration profile
$\bar{F}$	vector of BOD or OD sources
FF(x,t)	rate of increase of BOD at STP
f(x,t)	distribution of BOD
G	initial OD concentration profile
G(m,n,s)	probability generating function
g(x,t)	distribution of DO or OD
IPT	category index
K ₁ or K ₁ (x,t)	coefficient defining rate of deoxygenation
K ₂ or K ₂ (x,t)	coefficient defining rate of reaeration
K ₃ or K ₃ (x,t)	coefficient defining rate of deoxygenation due to benthic demand and algae
K ₄ or K ₄ (x,t)	K ₁ +K ₃
L	pollution variable
L _a	initial BOD concentration
L _m	concentration of state m
L ₀	initial pollution concentration
L _R or L _R (x,t)	rate of increase in BOD due to land runoff
M(x,t)	mean state concentration
m	position state value
m(x,t)	mean concentration

NF	number of grid spacings for BOD
NG	number of grid spacing in estuary for OD
NS	number of outputs
NV	variable number
n	time state value
OD	oxygen deficit
OMEGA	tidal frequency $2\pi/12.4$ for estuaries, 0 for river
OMEGAF	frequency of sinusoidal feed rate
o(h)	small with respect to h
PRI	interval in real time hours between outputs
P(s,r,t)	probability generating function for BOD and DO states
ppm	parts per million
p(t) or $\bar{p}(t)$	probability of a forward step in BOD or DO
q(t) or $\bar{q}(t)$	probability of a backward step in BOD or DO
R(x,t)	sources, sinks, coupling terms
r(t) or $\bar{r}(t)$	probability of absorption of BOD or DO
S	sources or sinks
STP	sewage treatment plant
TI	time at beginning of simulation
TM	time in hours at end of simulation
t	real time
U or U(x,t)	velocity function
UF	fresh water velocity
UT	tidal velocity
u(m,n)	probability of finding a BOD particle in state m,n
VAR	variance
V(m,n)	probability of finding an OD or DO particle in state m,n
W	rate of pollution loading
XI	upstream position, upper boundary of estuary in miles
XO	downstream boundary
XS(n)	the nth position for output
x	position along stream or estuary
α	confidence of confidence interval

Δ	stochastic parameter
δt	time increment
δx	space increment
λ	mean concentration input
$\mu(x, t)$	mean BOD concentration
$\bar{\mu}(x, t)$	mean OD concentration
$\sigma^2(x, t)$	variance BOD concentration
$\bar{\sigma}^2(x, t)$	variance OD concentration

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APPENDICES

PROGRAM LISTINGS

SAMPLE INPUT

SAMPLE OUTPUT


```

/* DIFFERENTIAL EQUATIONS PROGRAM
**
**
** PROGRAM TO DETERMINE BOD AND OD PROFILES IN AN ESTUARY WITH
** BOTH FRESH WATER AND TIDAL VELOCITIES.
**
** THIS PROGRAM USES RUNGE-KUTTA-MERSEN INTEGRATION IN TIME.
**
**
** POLUD: PROC OPTIONS(MAIN);
ON ERROR GO TO DATA;
UN ENDFILE(SYSIN) GO TO ENC2;
DCL XZ(200);
DCL L(-1:12) LABEL;
DCL XS(50),XM(151),NS;
DCL (UF(151),US(151),EG(151),EF(151),K1(151),K2(151),KD(151),DB
(151),LR(151)
DZ(302),D2(302),DX,DX60,DX2180,DX12,U,DU,XI,
PRI, I, OT) FLOAT;
DX212, TI, TM, IDNT(12) CHAR(20);
DCL
GF=0;
ABSE=10;
RELE=0.0001;
IDNT(1)= 'G PROFILE ';;
IDNT(2)= 'F PROFILE ';;
IDNT(3)= 'FRESH WATER VELOCITY';
IDNT(4)= 'TIDAL VELOCITY';
IDNT(5)= 'G DIFFUSIVITY';
IDNT(6)= 'F DIFFUSIVITY';
IDNT(7)= 'K1 PROFILE ';;
IDNT(8)= 'K2 PROFILE ';;
IDNT(9)= 'KD PROFILE ';;
IDNT(10)= 'DB PROFILE ';;
IDNT(11)= 'LR PROFILE ';;
IDNT(12)= 'F FEED RATES';

```

```

DATA:      GET LIST(NG,NF,XI,XO,TI,TM,PRI,      OMEGA,OMEGAF);
           PUT PAGE EDIT('INPUT DATA','NO. G INCREMENTS',NG,
'NO. F INCREMENTS',NF,'UPSTREAM X',XI,'DOWNSTREAM X',XO,
'INITIAL TIME',TI,'FINISH TIME',TM,
'PRINT INTERVAL',PRI,
'TIDAL FREQUENCY',OMEGA,'POLUTION FREQUENCY',OMEGAF)
(SKIP(5),X(50),A,2(SKIP(2),X(20),A(20),F(10)),15 (SKIP(2),X(20),
A(20),E(20,5)));
NGF=NF/NG;
TPR=TI;
T=TI;
DT=PRI/4 ;
JJ=1;
KK=NG+1;
J=NG+2;
K=NG+NF+2;
DXF=(XO-XI)/NF;
DXG=(XC-XI)/NG;
KL=NF+1;
XM(1)=XI;
DO I=2 TO KK;
XM(I)=XM(I-1)+DXG;
END;
L(0):      XZ(1)=XI;      DO I=2 TO KL;      XZ(I)=XZ(I-1)+DXF;      END;
           GET LIST(NS,(XS(I) DO I=1 TO NS));
           GET LIST(IPT,NV);
           GO TO L(NV);
L(1):      CALL STORE(JJ,KK,GF(1,*),DXG);
           DO I=1 TO KK;
           GF(1,I)=GF(1,I)*9.19E+06;
           END;
           GO TO L(NV);
L(2):      CALL STORE(J,K,GF(1,*),DXF);
           DO I=J TO K;
           GF(1,I)=GF(1,I)*9.19E+06;

```



```

/*****
RKMI: PROC(X,Y,E,A,J);
      DCL (X(*),Y(*),A(*),E(*),B(302),C(302),D(302),TQ) FLCAT;
      DCL I,J,L;
      J=3;
      L=0;
      TQ=0.0;
      DO I=2 TO KK, KK+2 TO K;
        T=T+D03;
        CALL FUNCT(X,B);
        DO I=2 TO KK, KK+2 TO K;
          X(I)=X(I)+D03*(B(I)-A(I))/2.0;
          CALL FUNCT(X,C);
          DO I=2 TO KK, KK+2 TO K;
            X(I)=X(I)+D03*(1.125*C(I)-0.5*B(I)-0.125*A(I));
          END;
          T=T+D02-D05;
          CALL FUNCT(X,D);
          DO I=2 TO KK, KK+2 TO K;
            X(I)=X(I)+D03*(1.125*A(I)-5.625*C(I)+6.0*D(I));
          END;
          T=T+D02;
          CALL FUNCT(X,E);
          DO I=2 TO KK, KK+2 TO K;
            TQ=A(I)-4.5*C(I)+4.0*D(I)-0.5*E(I);
            TQ=D015*TQ/(RELE*ABS(X(I))+ABSE);
            IF TQ>TQ THEN TQ=TQ;
            IF TQ>1.0 THEN GO TO BORN;
            IF TQ>0.1 THEN GO TO NWFN;
          J=1;
        J=2;
      NWFN: CALL FUNCT(X,E);
      BORN: T=T-DI;
      END RKMI;
/****
/

```

```

/* SUBROUTINE TO CONTROL PRINTOUT DURING INTEGRATION.
*/
*****
/ POUT: PROC;
      DCL I;
      ID=IA;
      TT=T;
      IF ABS(TPR-T)<.01*PRI THEN GO TO REDY;
      IF T+DZS<TPR THEN GO TO EPOU;
      DT=TPR-T;
      TT=T+DT;
      DO3=DT/3;
      DO2=DT/2;
      DO15=DT/15;
      CALL RKMI(GF(IB,*),GF(IA*),DGF(IB,*),DGF(IA*),JER);
      ID=IB;
      IF JER<3 & DT>.25*DZS THEN DC;
      T=T+DT;
      IB=IA;
      IA>ID;
      END;
      REDY: TPR=TPR+PRI;
            CALL STAPR;
      STAPR: PROC;
            DCL I,M,L,POS;
            ILC=ILC+1;
            IF ILC>5 THEN DO;
              ILC=0;
              PUT PAGE EDIT('TIME, HRS',TT,'DELTA T, HRS',DZS,'TIDE',TIDE)
                {SKIP(2),3(X(10),A(15),F(8,4))};
              PUT SKIP(2) EDIT('STATION POSITIONS',(XS(I) DO I=1 TC NS))
                (X(20),A,15 {SKIP,16 F(7,2)});
            END;
            ELSE PUT SKIP(3) EDIT('TIME, HRS',TT,'DELTA T, HRS',DZS,
              'TIDE',TIDE) (3(X(10),A(15),F(8,4)));

```



```

L=2;
DO I=1 TO KK;
  DZ(I)=GF(ID,I)/9.19E+06;
END;
DO I=1 TO NS;
  CALL INTP(L, KK, XM, DZ, XS(I), D2(I), ACR);
END;
PUT SKIP(2) EDIT('G--PROFILE', (D2(I) DO I=1 TO NS)) (X(20), A,
15 (SKIP, 16 F( 7, 3))) ;
/****
/*
/*
/*
/*
/*
/*
/*
/*
PUNCHED CARD OUTPUT OPTION
400 CAN BE REPLACED WITH ANY TIME GREATER THAN THE STEADY STATE
TIME. WITH THE PRESENT CARD, PUNCHED CARD OUTPUT WILL BE GIVEN
FOR ALL PRINT INTERVALS GREATER THAN 400 HOURS.
/****
/*
/*
/*
/*
/*
/*
/*
/*
IF T>400 THEN DO ; PUT FILE(PUNCH) EDIT(TIDE, (D2(I) DO I=1 TO NS),
TIDE) (2(X(8), 9 F(8, 3))) ; END ;
DO I=1 TO KL;
  M=I+KK;
  DZ(I)=GF(ID, M)/9.19E+06;
END;
DO I=1 TO NS;
  CALL INTP(L, KL, XZ, DZ, XS(I), D2(I), ACR);
END;
PUT SKIP(2) EDIT('F--PROFILE', (D2(I) DO I=1 TO NS)) (X(20), A,
15 (SKIP, 16 F( 7, 3))) ;
/****
/*
/*
/*
/*
/*
/*
/*
/*
PUNCHED CARD OUTPUT OPTION ---- SAME AS ABOVE
/****
/*
/*
/*
/*
/*
/*
/*
/*
IF T>400 THEN DO ; PUT FILE(PUNCH) EDIT(TIDE, (D2(I) DO I=1 TO NS),

```

```

TIDE) (2(X(8), 9 F(8,3))) ; END ;
END STAPR;
EPOU: END PCUT;
STORE:  PROC(M,MM,U,DX);
        DCL U(*) ,POS,ACR,I,J,N,M,MM;
        DCL NVS;
        NVS=NV;
        ACR=0.0001;
        IF IPT>0 THEN GO TO INTEP;
        IF IPT>-2 THEN GO TO DSCRT;
        GET LIST(POS,NV);
        DO I=M TO MM;
        U(I)=POS;
        END;
        GO TO RETUN;
DSCRT:  IF IPT<0 THEN DO I=M TO MM;    U(I)=0;    END;    N=1; XX=XI;
NEXPS:  GET LIST(POS);    IF POS<XI THEN GO TO RETRN;
        GET LIST(VAL);
NEWTY:  IF POS<XX THEN GO TO NEXTY;    IF IPT=0 THEN U(N)=VAL;
        N=N+1;    XX=XX+DX;    GO TO NEWTY;
NEXTY:  IF IPT<0 THEN DO;    IF ABS(U(N-1)-POS)>ABS(U(N)-POS)
        THEN U(N)=VAL;    ELSE U(N-1)=VAL;    END;    GO TO NEXPS;
INTEP:  GET LIST((DZ(I),D2(I)) DO I=1 TO IPT));
        POS=XI;
        J=2;
        DO I=M TO MM;
        CALL INTP(J,IPT,DZ,D2,POS,U(I),ACR);
        POS=POS+DX;
        END;
RETRN:  GET LIST(NV);
RETRN:  PUT SKIP EDIT(IDNT(NVS),(U(NVS) DO NVS=M TO MM))
        (SKIP(2),X(50),A,(20) (SKIP ,9 F(12,4)));
END STORE;

```

```

/*****
/*

```

```

SUBROUTINE TO PERFORM NONLINEAR INTERPOLATION

PARAMETERS ARE AS FOLLOWS:
LN = MAXIMUM POLYNOMIAL ORDER
NP = NUMBER OF PAIRS OF POINTS IN THE TABLE
X = VALUES OF THE INDEPENDENT VARIABLE ARRANGED IN ASCENDING
ORDER
FX = VALUES OF THE DEPENDENT VARIABLE CORRESPONDING TO X
XX = VALUE OF THE INDEPENDENT VARIABLE FOR WHICH A VALUE OF THE
DEPENDENT VARIABLE IS REQUIRED
FXX = VALUE OF THE DEPENDENT VARIABLE FOUND
ACC = DESIRED RELATIVE ACCURACY OF FXX

      PROC(LN,NP,X,FX,XX,FXX,ACC);
      DCL LN,NP,I,J,K,L,LL,MM,NN,X(*),FX(*),XX,FXX,Y(7),ACC,FYY
      ;
      IF ACC<1E-06 THEN ACC=1E-06;
      L=0;
      K=-1;
      MM=1;
      DO I=1 TO NP;
        IF X(I)<XX THEN GO TO ENIT;
        IF ABS(X(I)-XX)<=(ACC+ABS(XX))*ACC THEN DO;
          FY(1)=FX(I);
          GO TO GOIT;
        END;
        J=I;
        GO TO STRT;
      END;
      J=NP;
      L=-1;
      Y(1)=X(J)-XX;
      FY(1)=FX(J);
      FYY=FY(1);

ENIT:
STRT:

```



```

AIT1: IF L=0 THEN DC;
J=J+L;
GO TO REDY;
END;
J=J+K;
K=K-(2*K+SIGN(K));
IF J>NP THEN DC;
J=J+K;
L=-1;
GO TO REDY;
END;
IF J<1 THEN DO;
J=J+K;
L=1;
END;
MM=MM+1;
Y(MM)=X(J)-XX;
FY(MM)=FX(J);
LL=MM-1;
DO NN=1 TO LL;
FY(MM)=(FY(NN)*Y(MM)-FY(MM)*Y(NN))/(Y(MM)-Y(NN));
END;
IF LN=LL THEN GO TO GOIT;
IF ABS(FYY-FY(MM))<ACC*(ACC+ABS(FY(MM))) THEN GO TO GOIT;
IF MM>6 THEN GO TO GOIT;
FYY=FY(MM);
GO TO AIT1;
FXX=FY(MM);
END INTP;
PROC(X,X0);
DCL(X(*),XD(*)) FLOAT, L,1;
CALL FRSTD(JJ,KK,X,DZ);
CALL SCNDD(JJ,KK,X,DZ);
CALL FRSTD(J,K,X,DZ);
CALL SCNDD(J,K,X,DZ);

```

REDY:

GOIT:

FUNCT:

```

SNT=OMEGA*T;
SNT=SIN(SNT);
XABS=ABS(SNT);
SFT=OMEGA*T;
SFT=0.001*COS(SFT) + 1.0;

VARIABLE FEED RATES

SFT IS THE RATIO OF THE CURRENT FEED RATE TO THE AVERAGE FEED
RATE. ANY NEEDED MODIFICATION TO THE FUNCTIONAL FORM OF FF(T)
IS PERMITTED.
CURRENTLY FF(T) = FF*(1.0 + 0.001*COS(OMEGA*T))

L=1; M=KK+1;
DO I=2 TO KK;
  DO MM=1 TO NGF;
    L=L+1; M=M+1;
    U=UF(L)+US(L)*SNT;
    XD(M)=EF(L)*D2(M)-U*DZ(M)- ( KD(L)*X(M)+FF(L)*SFT+LR(I);
  END;
  XKSIN=K2(I)*XABS*1.5708;

CORRECTION FACIOR FOR K2(X)

IN THE FOLLOWING CARD REPLACE XKSIN WITH K2(I) IF SIMULATING
A RIVER.

XD(I)=EG(I)*D2(I)-U*DZ(I)-( XKSIN )*(X(I)+K1(I)+X(M)+DB(I) ;END;
RETRN;
END FUNCT;

EVALUATION OF THE FIRST DERIVATIVE WITH SIXTH ORDER ACCURACY

```



```

D(I)=(Y(I-2)-2*Y(I-1)+Y(I))/(DX*DX);
L=N+1;
D(L)=(Y(L+1)-2*Y(L)+Y(L-1))/(DX*DX);
L=M-1;
D(L)=(Y(L+1)-2*Y(L)+Y(L-1))/(DX*DX);
I=N+2;
D(I)=(-Y(I+2)+16*Y(I+1)-30*Y(I)+16*Y(I-1)-Y(I-2))/DX212;
I=M-2;
D(I)=(-Y(I+2)+16*Y(I+1)-30*Y(I)+16*Y(I-1)-Y(I-2))/DX212;
DO I=N+3 TO M-3;
D(I)=(2*(Y(I+3)+Y(I-3))-27*(Y(I+2)+Y(I-2))+270*(Y(I+1)+Y(I-1))
-490*Y(I))/DX2180;
END;
END SCNDD;
END POLUD;
ENC2:

```

DATA FOR PL/1 PROGRAM

```

60 120 0 30 0 500 1 .5067 .262
16 0 3 4.8 6 8 9 10 11 11.8 13 14 15 16 17.8 20 22
-2 1 0 2 0 5 0.1042 6 0.1042 7 0.020 9 0.020 11 20000 0 28 8
.673 .00208 2.02 0.00208 3.212 .00375 4.255 .00375 5.217 .00708 .09 .0071 6.008
.0154 7.5 .0154 8.307 .01290 9.3 .01290 10.237 .0163 11.29 .0163 12.463 .02292
13.75 .02292 14.937 .0133 16.03 .0133 17.19 .01040 18.41 .01040 19.535 .01333
20.565 .01333 21.643 .00958 22.77 .00958 24.318 .0108 26.29 .01083 28.015
.01083 29.48 .01083 30.955 .01166 32.42 .01166 0 28 10 .673 0 2.02 0
3.212 14900 4.255 14900 5.217 150700 6.09 150700 6.858 301400
7.5 301400 8.307 273500 9.3 273500 10.237 347300 11.29 347300 12.463 385500
13.75 385500 14.937 279700 16.03 279700 17.19 256800 18.41 256800 19.535 211500
20.57 211500 21.643 159900 22.77 159900 24.318 154100 26.29 134100 28.015
137600 29.48 137600 30.955 151500 32.42 151500 0
16.40 0.1.23 0.3863
3.735 .4421 5.655 .4812 7.185 .568 8.775 .805 10.765 1.042 13.105 1.12
15.485 1.144 17.8 1.168 20.05 1.19 22.205 1.2 25.305 1.2 28.75 1.112 31.68500
0.97 35.355 0.9233 0.14.3 0.507 2.69 .078 4.78 .096 6.53 .0807
7.84 .0682 9.71 .0715 11.82 .0524 14.39 .0510 16.58 .0572 19.02 .0423
21.08 .0375 23.33 .0294 27.28 .02245 30.22 .0192 0
-1 12 9 1.507E+06 10 1.120E+07 12.2 .728E+0
6 19.6 .37E+03 22 .18E+05 -1 -1

```

```

C *****
C
C DIFFERENTIAL EQUATIONS PROGRAM
C
C PROGRAM TO DETERMINE BOD AND OD PROFILES IN AN ESTUARY WITH
C BOTH FRESH WATER AND TIDAL VELOCITIES.
C
C THIS PROGRAM USES RUNGE-KUTTA-MERSEN INTEGRATION IN TIME.
C *****
C
C REAL K1,K2,KD,LR
C COMMON DZ(302),D2(302),DGF1(302),DGF2(302),
C 1DB(151),EF(151),EG(151),FF(151),GF1(302),GF2(302),K1(151),
C 2K2(151),KD(151),LR(151),XM(151),XZ(200),XS(50),UF(151),US(151),
C 3ABSE,DO3,DO2,DO15,DT,DZS,DX,DXF,DXG,DX60,DX12,DX2180,DX212,IA,IB,
C 4ILC,JJ,J,K,K,K,KL,NS,NGF,OMEGA,OMEGAF,T,TIDE,TPR,RELE,PRI,
C 5IPT,NV,XI
C CALL ERRSET( 208,260,-1,1,0)
C ABSE=10.
C RELE=.0001
C
C 1 READ (5,2,END=999) NG,NF,XI,XO,TI,TM,PRI,          OMEGA,OMEGAF
C 2 FORMAT (2I5,(7F10.4))
C WRITE(6,3) NG,NF,XI,XO,TI,TM,PRI,          OMEGA,OMEGAF
C 3 FORMAT('1.////50X','INPUT DATA'//20X,
C 1'NO. G INCREMENTS      ',110//20X,
C 2'NO. F INCREMENTS      ',110//20X,'UPSTREAM X',10X,E20.5//20X,
C 3'DOWNSTREAM X',8X,E20.5//20X,'INITIAL TIME',8X,E20.5//20X,
C 4'FINISH TIME',9X,E20.5//20X,'PRINT INTERVAL',6X,E20.5//20X,
C 5'TIDAL FREQUENCY',5X,E20.5//20X,'POLLUTION FREQUENCY ', E20.5)
C NGF=NF/NG
C TPR=TI
C T=TI
C DT=PRI/4.
C JJ=1
C KK=NG+1

```



```

J=NG+2
K=NG+NF+2
DXF=(XO-XI)/NF
DXG=(XC-XI)/NG
KL=NF+1
XM(1)=XI
DO 4 I=2,KK
4 XM(I)=XM(I-1)+DXG
XZ(1)=XI
DO 5 I=2,KL
5 XZ(I)=XZ(I-1)+DXF
READ(5,6,END=99) NS,(XS(I),I=1,NS)
6 FORMAT(15,SX,(7F10.4))
8 READ(5,7,END=99) IPT,NV
7 FORMAT(21S)
NV=NV+1
GO TO (21,8,9,10,11,12,13,14,15,16,17,18,19,20),NV
9 CALL STORE(JJ,KK,GFI,DXG)
DO 22 I=1,KK
22 GF1(I)=GF1(I)*9.19E+6
GO TO (21,8,9,10,11,12,13,14,15,16,17,18,19,20),NV
10 CALL STORE(J,K,GF1,DXF)
DO 23 I=J,K
23 GF1(I)=GF1(I)*9.19E+6
C*****
UPSTREAM BOUNDARY CONDITIONS
REPLACE 3.6 IN THE FOLLOWING TWO STATEMENTS WITH THE APPROPRIATE
UPSTREAM BOD CONCENTRATIONS IN PPM.
C*****
GF1(J)=3.6*9.19E+6
GF2(J)=3.6*9.19E+6
C*****

```

C
C
C
C
C

REPLACE 1.0 IN THE FOLLOWING TWO STATEMENTS WITH THE APPROPRIATE
UPSTREAM OD CONCENTRATIONS IN PPM.

```

GF1(I) = 1. *S.19E+6
GF2(I) = 1. *S.19E+6
GO TO (21,8,9,10,11,12,13,14,15,16,17,18,19,20),NV
11 CALL STORE (JJ,KL,UF,DXF)
12 CALL STORE (JJ,KL,US,DXF)
DO 25 I=1,KL
25 US(I)=US(I)*1.5
GO TO (21,8,9,10,11,12,13,14,15,16,17,18,19,20),NV
13 CALL STORE (JJ,KK,EG,DXG)
GO TO (21,8,9,10,11,12,13,14,15,16,17,18,19,20),NV
14 CALL STORE (JJ,KL,EF,DXF)
GO TO (21,8,9,10,11,12,13,14,15,16,17,18,19,20),NV
15 CALL STORE (JJ,KK,K1,DXG)
GO TO (21,8,9,10,11,12,13,14,15,16,17,18,19,20),NV
16 CALL STORE (JJ,KK,K2,DXG)
GO TO (21,8,9,10,11,12,13,14,15,16,17,18,19,20),NV
17 CALL STORE (JJ,KL,KD,DXF)
GO TO (21,8,9,10,11,12,13,14,15,16,17,18,19,20),NV
18 CALL STORE (JJ,KK,DB,DXG)
GO TO (21,8,9,10,11,12,13,14,15,16,17,18,19,20),NV
19 CALL STORE (JJ,KL,LR,DXF)
GO TO (21,8,9,10,11,12,13,14,15,16,17,18,19,20),NV
20 CALL STORE (JJ,KL,FF,DXF)
DO 30 I=1,KL
30 FF(I)=FF(I)/DXF
GO TO (21,8,9,10,11,12,13,14,15,16,17,18,19,20),NV
21 WRITE(6,31)
31 FORMAT('1.0')
ILC=150

```

```

35 IA=1
   IB=2
   CALL FUNCT(GF1,DGF1)
   GO TO 39
36 D02=DT/2.
   D03=DT/3.
   D015=DT/15.
37 IF(T+DT.GT.TM) GO TO 40
   GO TO (112,121),IA
112 CALL RKMI(GF2,GF1,DGF2,DGF1,IER)
   GO TO 123
121 CALL RKMI(GF1,GF2,DGF1,DGF2,IER)
123 IF (IER.NE.3) GO TO 41
   DT=DT/2.
   GO TO 36
41 IC=IA
   IA=IB
   IB=IC
   T=T+DT
   IF (IER.EQ.1) GO TO 39
   DT=4.*DT/3.
   IF(DT.GT.PRI) DT=PRI
39 DZS=DT
   TIDE=T/12.4
   CALL POUT
   DT=DZS
   GO TO 36
40 WRITE(6,42)
42 FORMAT('///SOLUTION IS COMPLETE')
   GO TO 1
999 STOP
   END

```



```

SUBROUTINE RKMI(X,Y,E,A,J1)
C *****
C
C SUBROUTINE TO CARRY OUT ONE STEP OF THE RUNGE-KUTTA-MERSEN
C INTEGRATION. CALLS SUBROUTINE NAMED "FUNCT".
C *****
C *****
DIMENSION X(1),Y(1),A(1),E(1),B(302),C(302),D(302)
REAL K1,K2,KD,LR
COMMON DZ(302),D2(302),DGF1(302),DGF2(302),
1DB(151),EF(151),EG(151),FF(151),GF1(302),GF2(302),K1(151),
2K2(151),KD(151),LR(151),XM(151),XZ(200),XS(50),UF(151),US(151),
3ABSE,D03,D02,D015,DT,DZS,DX,DXF,DXG,DX60,DX12,DX2180,EX212,IA,IB,
4ILC,JJ,J,K,KL,NS,NGF,OMEGA,OMEGAF,T,TIDE,TPR,RELE,PRI,
5IPT,NV,XI
J1=3
L=0
T00=0.
DO 1 I=2,KK
1 X(I)=Y(I)+ D03*A(I)
KK2=KK+2
DO 2 I=KK2,K
2 X(I)=Y(I) + D03*A(I)
T=T + D03
CALL FUNCT(X,B)
DO 3 I=2,KK
3 X(I)=X(I) + D03*(B(I)-A(I))/2.
DO 4 I=KK2,K
4 X(I)=X(I) + D03*(B(I)-A(I))/2.
CALL FUNCT(X,C)
DO 5 I=2,KK
5 X(I)=X(I) + D03*(1.125*C(I)-.5*B(I)-.125*A(I))
DO 6 I=KK2,K
6 X(I)=X(I) + D03*(1.125*C(I)-.5*B(I)-.125*A(I))
T=T + D02 -DC3

```

```

CALL FUNCT(X,D)
DO 7 I=2,KK
7 X(I)=X(I) + D03*(1.125*A(I)-5.625*C(I) + 6.*D(I))
DO 8 I=KK2,K
8 X(I)=X(I) + D03*(1.125*A(I)-5.625*C(I) + 6.*D(I))
T=T + D02
CALL FUNCT (X,E)
DO 9 I=2,KK
TQ=A(I)-4.5*C(I) + 4.*D(I) -.5*E(I)
X(I)=X(I) -D03*TQ
TQ=D015 * TQ /(RELE * ABS(X(I)) + ABSE)
TQ=ABS(TQ)
IF (TQ.GT.TQQ) TQQ=TQ
9 CONTINUE
DO 12 I=KK2,K
TQ=A(I)-4.5*C(I) + 4.*D(I) -.5*E(I)
X(I)=X(I) -D03*TQ
TQ=D015 * TQ /(RELE * ABS(X(I)) + ABSE)
TQ=ABS(TQ)
IF (TQ.GT.TQQ) TQQ=TQ
12 CONTINUE
IF (TQQ.GT.1.) GO TO 10
J1=1
IF (TQQ.GT. .1) GO TO 11
J1=2
11 CALL FUNCT(X,E)
10 T=T-DT
RETURN
END

```

SUBROUTINE PCUT

C*****
C

```

C      SUBROUTINE TO CONTROL PRINTOUT DURING INTEGRATION.
C
C*****
      REAL K1,K2,KD,LR
      COMMON DZ(302),D2(302),DGF1(302),DGF2(302),
10B(151),EF(151),EG(151),FF(151),GF1(302),GF2(302),K1(151),
2K2(151),KD(151),LR(151),XM(151),XZ(200),XS(50),UF(151),US(151),
3ABSE,DC3,DC2,DO15,DT,DZS,DX,DXF,DXG,DX60,DX12,DX2180,DX212,IA,IB,
4ILC,JJ,J,K,KL,NS,NGF,CMEGA,OMEGAF,T,TIDE,TPR,RELE,PRI,
5IPT,NV,XI
      ID=IA
      TT=T
      IF(ABS(TPR-T).LT. .01*PRI) GO TO 21
      IF(T + DZS .LT. TPR) GO TO 22
      DT=TPR-T
      TT=T+DT
      DO3=DT/3.
      DO2=DT/2.
      DO15=DT/15.
      GO TO (112,121),IA
112 CALL RKMI(GF2,GF1,DGF2,DGF1,JER)
      GO TO 123
121 CALL RKMI(GF1,GF2,DGF1,DGF2,JER)
123 ID=IR
      IF(JER.LT. 3 .AND. DT.GT. .25*DZS) GO TO 23
      GO TO 21
23 T=T+DT
      IB=IA
      IA=ID
21 TPR=TPR +PRI
      ILC=ILC +1
      IF(ILC.LE.5) GO TO 3
      ILC=0
      WRITE(6,1) TT,DZS,TIDE
1 FORMAT('1. / 10X,TIME, HRS',6X,F8.4,10X,'DELTA T, HRS ',F8.4,

```



```

M=I + KK
204 DZ(I)=GF2(M)/9.19E+6
205 DO 10 I=1,NS
10 CALL INTP(L,KL,XZ,DZ,XS(I),D2(I),ACR)
WRITE(6,11) (D2(I),I=1,NS)
11 FORMAT( /20X,'F--PROFILE',/(16F7.3))
C*****
C PUNCHED CARD OUTPUT OPTION ---- SAME AS ABOVE
C*****
C IF(T.GT.400) WRITE(7,8) TIDE,(D2(I),I=1,NS),TIDE
22 RETURN
END

```

```

SUBROUTINE STORE(M,MM,U,DX1)
DIMENSION IDNT(60), U(1)
REAL K1,K2,KD,LR
COMMON DZ(302),D2(302),DGF1(302),DGF2(302),
10B(151),EF(151),EG(151),FF(151),GF1(302),GF2(302),K1(151),
2K2(151),KD(151),LR(151),XM(151),XZ(200),XS(50),UF(151),US(151),
3ABSE,DO3,DO2,DO15,DT,DZS,DX,DXF,DXG,DX60,DX12,DX2180,DX212,1A,1B,
4ILC,JJ,J,K,K,K,KL,NS,NGF,OMEGA,OMEGAF,T,TIDE,TPR,RELE,PRI,
5IPT,NV,XI
DATA IDNT( 1),IDNT( 2),IDNT( 3),IDNT( 4),IDNT( 5),IDNT( 6),
1 IDNT( 7),IDNT( 8),IDNT( 9),IDNT(10),IDNT(11),IDNT(12),
2 IDNT(13),IDNT(14),IDNT(15),IDNT(16),IDNT(17),IDNT(18),
3 IDNT(19),IDNT(20),IDNT(21),IDNT(22),IDNT(23),IDNT(24),
4 IDNT(25),IDNT(26),IDNT(27),IDNT(28),IDNT(29),IDNT(30)
/ 'G PR','CFIL','E',,,'',
'F PR','CFIL','E',,,'',
'FRES','H WA','TER',,,'VFLO','CITY',
'TIDA','L VE','LOCI','TY',,,'',

```

```

9 # DATA IDNT(31), IDNT(32), IDNT(33), IDNT(34), IDNT(35), IDNT(36),
      'G DI', 'FFUS', 'IVIT', 'Y', 'Y',
      'F DI', 'FFUS', 'IVIT', 'Y', 'Y',
      IDNT(37), IDNT(38), IDNT(39), IDNT(40), IDNT(41), IDNT(42),
      IDNT(43), IDNT(44), IDNT(45), IDNT(46), IDNT(47), IDNT(48),
      IDNT(49), IDNT(50), IDNT(51), IDNT(52), IDNT(53), IDNT(54),
      IDNT(55), IDNT(56), IDNT(57), IDNT(58), IDNT(59), IDNT(60),
      /
      'K1 P', 'ROFI', 'LE', 'Y',
      'K2 P', 'ROFI', 'LE', 'Y',
      'K3 P', 'ROFI', 'LE', 'Y',
      'DB P', 'ROFI', 'LE', 'Y',
      'LR P', 'ROFI', 'LE', 'Y',
      'F FE', 'ED R', 'ATES', 'Y',
      /
      NVS=NVS - 2
      ACR=.0001
      IF(IPT.GT.0) GO TO 11
      IF(IPT.GT.-2) GO TO 3
      READ(5,1) PCS,NV
      1 FORMAT (F10.4,I5)
      NV= NV + 2
      DO 2 I=M,MM
      2 U(I)=PCS
      GO TO 17
      3 IF(IPT.GE.0) GO TO 5
      DO 4 I=M,MM
      4 U(I)=0.
      5 N=1
      XX=0.
      6 READ(5,7) PCS
      7 FORMAT(F10.4)
      IF(PCS.LT.XI) GO TO 13
      READ(5,12) VAL
      12 FORMAT(E10.4)
      8 IF(PCS.LT.XX) GO TO 9
      IF(IPT.EQ.0) U(N)=VAL

```



```

N=N+1
XX=XX+DX1
GO TO 8
9 IF(IPT.GE. 0) GC TC 6
IF(ABS(U(N-1)-POS).GT.ABS(U(N)-POS)) GO TO 10
U(N-1)= VAL
GO TO 6
10 U(N)=VAL
GO TO 6
11 READ (5,25) (DZ(I),D2(I),I=1,IPT)
25 FORMAT (8F10.4)
POS=XI
J1=2
00 15 I=M,MM
CALL INTP(J1,IPT,DZ,D2,POS,U(I),ACR)
15 POS=POS + DX1
13 READ (5,16) NV
16 FORMAT (I5)
NV= NV + 2
17 NVS=(NVS -1) * 5 + 1
NVS4= NVS + 4
WRITE(6,19) (IDNT(I1),J1=NVS,NVS4),(U(I),I=M,MM)
19 FORMAT(/50X,5A4,20(/9E12.4))
RETURN
END

SUBROUTINE FUNCT(X,XD)
REAL K1,K2,KD,LR
DIMENSION X(1),XD(1)
COMMON DZ(302),D2(302),DGF1(302),DGF2(302),
1DB(151),EF(151),EG(151),FF(151),GF1(302),GF2(302),K1(151),
2K2(151),KD(151),LR(151),XM(151),XZ(200),XS(50),UF(151),US(151),
3ABSE,D03,D02,D015,DT,DZS,DX,DXF,DXG,DX60,DX12,DX218U,DX212,IA,IB,

```



```

D(I)=(Y(I+1)-Y(I-1))/(2.*DX)
I=M-2
D(I)=(-Y(I+2)+8.*Y(I+1)-8.*Y(I-1)+Y(I-2))/DX12
I=M+2
D(I)=(-Y(I+2)+8.*Y(I+1)-8.*Y(I-1)+Y(I-2))/DX12
N3=N+3
M3=M-3
DO 3 I=N3,M
3 D(I)=(Y(I+3)-Y(I-3)-9.*Y(I+2)-Y(I-2))+45.*(Y(I+1)-Y(I-1)))/DX60
RETURN
END

```

```

SUBROUTINE SCMD(N,M,Y,D)
C
C
C      EVALUATION OF THE SECOND DERIVATIVE WITH SIXTH ORDER ACCURACY
C
C      REAL K1,K2,KD,LR
C      DIMENSION C(1),Y(1)
C      COMMON DZ(302),D2(302),DGFI(302),DGF2(302),
1DB(151),EF(151),EG(151),FF(151),GFI(302),GF2(302),K1(151),
2K2(151),KD(151),LR(151),XM(151),XZ(200),XS(50),UF(151),US(151),
3ABSE,DBE,DB2,DB15,DY,DZS,DX,DXF,DXG,DX60,DX12,DX218,IA,IB,
4ILC,JJ,J,K,KL,NS,NGF,OMEGA,OMEGAF,T,TIDE,TPP,RELE,PRI,
5IPT,NV,XI
IF(M.GT.KK) GO TO 1
DX=DXG
GO TO 3
1 DX=DXF
3 DX218=.3.*DX+DX60
DX212=UX+DX12
I=N

```

```

D(I)=(Y(I+2)-2.*Y(I+1)+Y(I))/(DX*DX)
I=M
D(I)=(Y(I-2)-2.*Y(I-1)+Y(I))/(DX*DX)
L=N+1
D(L)=(Y(L+1)-2.*Y(L)+Y(L-1))/(DX*DX)
L=M-1
D(L)=(Y(L+1)-2.*Y(L)+Y(L-1))/(DX*DX)
I=N+2
D(I)=(-Y(I+2)+15.*Y(I+1)-30.*Y(I)+15.*Y(I-1)-Y(I-2))/DX212
I=M-2
D(I)=(-Y(I+2)+15.*Y(I+1)-30.*Y(I)+15.*Y(I-1)-Y(I-2))/DX212
N3=N+3
M3=M-3
DO 2 I=N3,M3
2 D(I)=(2.*Y(I+2)+Y(I-3))-27.*Y(I+2)+Y(I-2))+270.*Y(I+1)
1 +Y(I-1))-450.*Y(I))/DX2180
RETURN
END

```

```

SUBROUTINE INTP(LN,NP,X,FX,XX,FXX,ACC)

```

```

SUBROUTINE TO PERFORM NONLINEAR INTERPOLATION

```

```

PARAMETERS ARE AS FOLLOWS:

```

```

LN = MAXIMUM POLYNOMIAL ORDER      0 < LN < 7

```

```

NP = NUMBER OF PAIRS OF POINTS IN THE TABLE

```

```

X = VALUES OF THE INDEPENDENT VARIABLE ARRANGED IN ASCENDING
ORDER

```

```

FX = VALUES OF THE DEPENDENT VARIABLE CORRESPONDING TO X

```

```

XX = VALUE OF THE INDEPENDENT VARIABLE FOR WHICH A VALUE OF THE
DEPENDENT VARIABLE IS REQUIRED

```

```

FXX = VALUE OF THE DEPENDENT VARIABLE FOUND

```

C ACC = DESIRED RELATIVE ACCURACY OF FXX

C *****

DIMENSION FY(7), Y(7), X(101), FX(101)

L=0

K=-1

MM=1

DO 90 I=1,NP

IF(X(I)-XX) 90,91,91

91 IF(ABS(X(I)-XX)-(ACC+ABS(XX))*ACC)92,92,93

92 FY(I)=FX(I)

GO TO 94

93 J=I

GO TO 95

90 CONTINUE

J=NP

L=-1

95 Y(1)=X(J)-XX

FY(1)=FX(J)

FYY=FY(1)

96 IF(L) 97,58,57

97 J=J+L

GO TO 99

98 J=J+K

IF(K) 1,2,3

1 XK=-1.

GO TO 4

2 XK=0.0

GO TO 4

3 XK=1.

4 K=K-(2*K+XK)

IF(J-NP)101,101,100

100 J=J+K

L=-1

GO TO 95


```

101 IF(J-1) 102,99,99
102 J=J+K
    L=1
99 MM=MM+1
    Y(MM)=X(J)-XX
    FY(MM)=FX(J)
    LL=MM-1
    DO 104 NN=1,LL
104 FY(MM)=(FY(NN)*Y(MM)-FY(MM)*Y(NN))/(Y(MM)-Y(NN))
    IF(LN-LL) 105,94,105
105 IF(ABS(FY-FY(MM))-ACC*(ACC+ABS(FY(MM)))) 94,106,106
106 IF(MM-6) 107,107,94
107 FYY=FY(MM)
    GO TO 96
94 FXX=FY(MM)
    RETURN
    END

```

DATA FOR FORTRAN 4 PROGRAM

60	120	0.	30.	0.	500.	1.	.5067	.262
16	0.	0.	3.	4.8	6.	8.	9.	10.
11.	11.8		13.	14.	15.	16.	17.8	
20.	22.							
-2	1							
0.	2							
0.	5							
0.1042	6							
0.1042	7							
0.020	9							
0.020	11							
20000.	0							
28	8							
.673	.00208	2.02	.00208	.0071	3.212	.00375	4.255	.00375
5.217	.00708	.09	.00708	.0129	6.858	.0154	7.5	.0154
8.307	.0129	9.3	.0129	.02292	10.237	.0163	11.29	.0163
12.463	.02292	13.75	.02292	.0104	14.937	.0133	16.03	.0133
17.19	.0104	18.41	.0104	.00958	19.535	.01333	20.565	.01333
21.643	.00958	22.77	.00958	.01083	24.318	.0108	26.29	.01083
28.015	.01083	29.48	.01083		30.955	.01166	32.42	.01166
0								
28	10							
.673	0.	2.02	0.	0.	3.212	14900.	4.255	14900.
5.217	150700.	6.09	150700.	150700.	6.858	301400.	7.5	301400.
8.307	273500.	9.3	273500.	273500.	10.237	347300.	11.29	347300.
12.463	385500.	13.75	385500.	385500.	14.937	279700.	16.03	279700.
17.19	256800.	18.41	256800.	256800.	19.535	211500.	20.57	211500.
21.643	159900.	22.77	159900.	159900.	24.318	154100.	26.29	154100.
28.015	137600.	29.48	137600.	137600.	30.955	151500.	32.42	151500.

NO. G INCREMENTS	60
NO. F INCREMENTS	120
UPSTREAM X	0.0
DOWNSTREAM X	0.30000E 02
INITIAL TIME	0.0
FINISH TIME	0.50000E 03
PRINT INTERVAL	0.10000E 01
TICAL FREQUENCY	0.50671E 00
POLLUTION FREQUENCY	0.26200E 00

[illegible][illegible][illegible]

[illegible]

K2 PROFILE											
0.2080E-02	0.2080E-02	0.2081E-02	0.2080E-02	0.2080E-02	0.2967E-02	0.3583E-02	0.3750E-02	0.3750E-02	0.3750E-02	0.3750E-02	0.3750E-02
0.4452E-02	0.6154E-02	0.1495E-01	0.1519E-01	0.1534E-01	0.1540E-01	0.1540E-01	0.1540E-01	0.1399E-01	0.1290E-01	0.1290E-01	0.1290E-01
0.1290E-01	0.1389E-01	0.1574E-01	0.1630E-01	0.1630E-01	0.1795E-01	0.2106E-01	0.2292E-01	0.2292E-01	0.2292E-01	0.2292E-01	0.2292E-01
0.2292E-01	0.2066E-01	0.1568E-01	0.1330E-01	0.1330E-01	0.1330E-01	0.1178E-01	0.1040E-01	0.1040E-01	0.1040E-01	0.1040E-01	0.1040E-01
0.1040E-01	0.1075E-01	0.1252E-01	0.1328E-01	0.1333E-01	0.1333E-01	0.1130E-01	0.9866E-02	0.9580E-02	0.9580E-02	0.9580E-02	0.9580E-02
0.5800E-02	0.5828E-02	0.1229E-01	0.1364E-01	0.1080E-01	0.1081E-01	0.1082E-01	0.1082E-01	0.1082E-01	0.1082E-01	0.1082E-01	0.1082E-01
0.1083E-01	0.1083E-01	0.1183E-01	0.1083E-01	0.1083E-01	0.1085E-01	0.1122E-01	0.1083E-01	0.1083E-01	0.1083E-01	0.1083E-01	0.1083E-01

DB PROFILE											
U.O	U.O	C.O	C.O	U.O	U.O	U.O	U.O	U.O	U.O	U.O	U.O
C.630UE 05	C.1325E 06	C.1507E 06	C.1507E 06	C.2516E 06	C.7911E 04	C.1341E 05	C.1490E 05	C.1490E 05	C.1490E 05	C.1490E 05	C.1490E 05
U.2735E 06	C.2951E 06	C.3352E 06	C.3473E 06	C.3473E 06	C.3560E 06	C.3748E 06	C.3855E 06	C.3855E 06	C.3855E 06	C.3855E 06	C.3855E 06
C.3655E 06	C.3541E 06	C.3058E 06	C.2797E 06	C.2797E 06	C.2797E 06	C.2677E 06	C.2590E 06	C.2590E 06	C.2590E 06	C.2590E 06	C.2590E 06
C.2560E 06	C.2514E 06	C.2272E 06	C.2122E 06	C.2115E 06	C.2115E 06	C.1840E 06	C.1639E 06	C.1599E 06	C.1599E 06	C.1599E 06	C.1599E 06
C.1599E 06	C.1587E 06	C.1505E 06	C.1549E 06	C.1541E 06	C.1541E 06	C.1541E 06	C.1541E 06	C.1541E 06	C.1541E 06	C.1541E 06	C.1541E 06
C.1451E 06	C.1407E 06	C.1377E 06	C.1376E 06	C.1376E 06	C.1379E 06	C.1441E 06					

TIDAL VELOCITY												
0.0	0.9766E-01	0.1855E-01	0.2637E-00	0.3320E-00	0.3868E-00	0.3926E-00	0.3983E-00	0.4040E-00	0.4097E-00	0.4154E-00	0.4211E-00	0.4268E-00
0.0497E+00	0.4531E-01	0.4420E-00	0.4263E-00	0.4317E-00	0.4371E-00	0.4421E-00	0.4429E-00	0.4430E-00	0.4430E-00	0.4430E-00	0.4430E-00	0.4430E-00
0.04464E+00	0.4531E-01	0.4591E-00	0.4665E-00	0.4752E-00	0.4826E-00	0.4887E-00	0.4983E-00	0.5126E-00	0.5268E-00	0.5410E-00	0.5552E-00	0.5694E-00
0.05242E+00	0.5501E-00	0.5785E-00	0.6183E-00	0.6571E-00	0.6948E-00	0.7314E-00	0.7670E-00	0.8016E-00	0.8362E-00	0.8708E-00	0.9054E-00	0.9400E-00
0.06357E+00	0.8758E-00	0.9095E-00	0.9407E-00	0.9695E-00	0.9957E-00	0.1019E-01	0.1041E-01	0.1052E-01	0.1063E-01	0.1074E-01	0.1085E-01	0.1096E-01
0.07638E+00	0.1072E-01	0.1081E-01	0.1090E-01	0.1098E-01	0.1105E-01	0.1112E-01	0.1118E-01	0.1124E-01	0.1129E-01	0.1135E-01	0.1140E-01	0.1146E-01
0.01124E+01	0.1126E-01	0.1129E-01	0.1131E-01	0.1134E-01	0.1137E-01	0.1139E-01	0.1142E-01	0.1144E-01	0.1146E-01	0.1148E-01	0.1150E-01	0.1152E-01
0.01147E+01	0.1149E-01	0.1152E-01	0.1155E-01	0.1157E-01	0.1160E-01	0.1162E-01	0.1165E-01	0.1167E-01	0.1169E-01	0.1171E-01	0.1173E-01	0.1175E-01
0.01170E+01	0.1173E-01	0.1176E-01	0.1179E-01	0.1181E-01	0.1184E-01	0.1186E-01	0.1188E-01	0.1190E-01	0.1192E-01	0.1194E-01	0.1196E-01	0.1198E-01
0.01191E+01	0.1193E-01	0.1194E-01	0.1195E-01	0.1197E-01	0.1198E-01	0.1199E-01	0.1200E-01	0.1200E-01	0.1200E-01	0.1200E-01	0.1200E-01	0.1200E-01
0.01200E+01	0.1200E-01	0.1200E-01	0.1200E-01	0.1200E-01	0.1200E-01	0.1200E-01	0.1200E-01	0.1200E-01	0.1200E-01	0.1200E-01	0.1200E-01	0.1200E-01
0.01200E+01	0.1200E-01	0.1200E-01	0.1200E-01	0.1200E-01	0.1200E-01	0.1200E-01	0.1200E-01	0.1200E-01	0.1200E-01	0.1200E-01	0.1200E-01	0.1200E-01
0.01167E+01	0.1161E-01	0.1154E-01	0.1146E-01	0.1138E-01	0.1130E-01	0.1121E-01	0.1112E-01	0.1103E-01	0.1094E-01	0.1085E-01	0.1076E-01	0.1067E-01
0.01081E+01	0.1067E-01	0.1053E-01	0.1040E-01	0.1028E-01	0.1016E-01	0.1004E-01	0.9928E-02	0.9808E-02	0.9688E-02	0.9568E-02	0.9448E-02	0.9328E-02

FRESH WATER VELOCITY											
0.5070E-00	0.4457E-00	0.3886E-00	0.3362E-00	0.2881E-00	0.2444E-00	0.2030E-00	0.1701E-00	0.1395E-00	0.1134E-00	0.9160E-01	0.7917E-01
0.5588E-01	0.5062E-01	0.4416E-01	0.3920E-01	0.3490E-01	0.3127E-01	0.2830E-01	0.2581E-01	0.2366E-01	0.2174E-01	0.2000E-01	0.1841E-01
0.7775E-01	0.7481E-01	0.7232E-01	0.7027E-01	0.6867E-01	0.6723E-01	0.6593E-01	0.6475E-01	0.6366E-01	0.6264E-01	0.6168E-01	0.6078E-01
0.7245E-01	0.7245E-01	0.7201E-01	0.7099E-01	0.6792E-01	0.6507E-01	0.6245E-01	0.6006E-01	0.5790E-01	0.5596E-01	0.5426E-01	0.5277E-01
0.5959E-01	0.5426E-01	0.5277E-01	0.5200E-01	0.5151E-01	0.5112E-01	0.5081E-01	0.5059E-01	0.5046E-01	0.5034E-01	0.5026E-01	0.5020E-01
0.5042E-01	0.5047E-01	0.5061E-01	0.5083E-01	0.5175E-01	0.5329E-01	0.5459E-01	0.5544E-01	0.5584E-01	0.5606E-01	0.5620E-01	0.5628E-01
0.5703E-01	0.5736E-01	0.5745E-01	0.5730E-01	0.5584E-01	0.5392E-01	0.5211E-01	0.5041E-01	0.4881E-01	0.4731E-01	0.4592E-01	0.4464E-01
0.4731E-01	0.4592E-01	0.4464E-01	0.4346E-01	0.4233E-01	0.4189E-01	0.4140E-01	0.4089E-01	0.4043E-01	0.4000E-01	0.3959E-01	0.3921E-01
0.3973E-01	0.3910E-01	0.3844E-01	0.3773E-01	0.3678E-01	0.3576E-01	0.3477E-01	0.3382E-01	0.3291E-01	0.3203E-01	0.3119E-01	0.3039E-01
0.3243E-01	0.3120E-01	0.3040E-01	0.2964E-01	0.2904E-01	0.2852E-01	0.2801E-01	0.2752E-01	0.2703E-01	0.2658E-01	0.2610E-01	0.2565E-01
0.2658E-01	0.2610E-01	0.2565E-01	0.2522E-01	0.2475E-01	0.2430E-01	0.2390E-01	0.2359E-01	0.2321E-01	0.2285E-01	0.2249E-01	0.2215E-01
0.2285E-01	0.2249E-01	0.2215E-01	0.2182E-01	0.2150E-01	0.2120E-01	0.2090E-01	0.2062E-01	0.2035E-01	0.2009E-01	0.1984E-01	0.1961E-01
0.2009E-01	0.1984E-01	0.1961E-01	0.1939E-01								

[illegible]

TIME, HRS	C.0	DELTA T, HRS	C.2500	TIDE	0.0
STATION POSITIONS					
0.0	4.80	6.00	8.00	9.00	10.00
1.000	0.00	0.00	0.00	0.00	0.00
3.600	0.00	0.00	0.00	0.00	0.00
G--PRCFILE					
F--PRCFILE					
TIME, HRS	1.0000	DELTA T, HRS	0.0741	TIDE	0.0774
G--PRCFILE					
1.000	0.001	0.010	0.017	0.031	0.032
3.600	0.002	0.002	0.003	0.014	0.016
F--PRCFILE					
TIME, HRS	2.0000	DELTA T, HRS	0.0988	TIDE	0.1543
G--PRCFILE					
1.000	0.004	0.013	0.030	0.062	0.063
3.600	0.010	0.004	0.004	0.005	0.005
F--PRCFILE					
TIME, HRS	3.0000	DELTA T, HRS	0.0988	TIDE	0.2409
G--PRCFILE					
1.000	0.103	0.012	0.035	0.081	0.050
3.600	0.288	0.007	0.006	0.007	0.124
F--PRCFILE					
TIME, HRS	4.0000	DELTA T, HRS	0.0988	TIDE	0.3206
G--PRCFILE					
1.000	0.432	0.024	0.036	0.091	0.107
3.600	1.251	0.036	0.009	0.009	0.129
F--PRCFILE					
TIME, HRS	5.0000	DELTA T, HRS	0.1317	TIDE	0.4022


```

C ESTUARY PROGRAM FOR DELTA VALUES
C
C *****
C
C AN AVERAGE DELTA IS CALCULATED FOR EACH SAMPLING STATION
C OF INTEREST.
C
C DATA INPUT FOR EACH STATION:
C 1. HEADER CARD GIVING THE STATION NUMBER, THE NUMBER
C OF OBSERVATIONS TAKEN, NI, AND THE TIME OF
C HIGH TIDE ON THE FIRST DAY THAT THE SURVEY
C BEGAN. FORMAT(2I5,F10.4)
C 2. NI SAMPLE CARDS GIVING THE MONTH, DAY, AND
C TIME THAT THE SAMPLE WAS TAKEN AND THE DO
C VALUE. FORMAT(2I5,2F10.4).
C
C INTERNAL ADJUSTMENTS REQUIRED:
C 1. INDICATED STATEMENTS IN MAIN PROGRAM MUST
C BE CHANGED IF DIFFERENT TIME SEGMENTS IN THE
C DAY ARE TO BE CONSIDERED. NOTE, TIME IS
C GIVEN IN MILITARY NOTATION.
C 2. THE FIRST DAY THAT SURVEY BEGAN MUST BE
C CODED INTO THE TID12 SUBROUTINE, STATE-
C MENTS 7 THROUGH 10. JUNE 20 IS THE DAY
C FOR THIS EXAMPLE AND DATA RUNS FROM JUNE 20
C UNTIL JULY 20.
C
C COMPUTATIONS:
C FOR EACH STATION THE NI SAMPLE CARDS ARE READ, ONE AT A TIME.
C A CHECK IS MADE ON THE TIME OF DAY THAT THE SAMPLE WAS TAKEN.
C IF OUTSIDE THE INTERVAL OF INTEREST THE SAMPLE IS DISREGARD-
C ED IN THE COMPUTATIONS WHICH FOLLOW. USING THE MONTH,
C DAY, AND HOUR THAT THE SAMPLE WAS TAKEN, THE TIDAL PHASE AT

```

AN AVERAGE DELTA IS CALCULATED FOR EACH SAMPLING STATION OF INTEREST.

DATA INPUT FOR EACH STATION:

1. HEADER CARD GIVING THE STATION NUMBER, THE NUMBER OF OBSERVATIONS TAKEN, NI, AND THE TIME OF HIGH TIDE ON THE FIRST DAY THAT THE SURVEY BEGAN. FORMAT(2I5,F10.4)
2. NI SAMPLE CARDS GIVING THE MONTH, DAY, AND TIME THAT THE SAMPLE WAS TAKEN AND THE DO VALUE. FORMAT(2I5,2F10.4).

INTERNAL ADJUSTMENTS REQUIRED:

1. INDICATED STATEMENTS IN MAIN PROGRAM MUST BE CHANGED IF DIFFERENT TIME SEGMENTS IN THE DAY ARE TO BE CONSIDERED. NOTE, TIME IS GIVEN IN MILITARY NOTATION.
2. THE FIRST DAY THAT SURVEY BEGAN MUST BE CODED INTO THE TID12 SUBROUTINE, STATEMENTS 7 THROUGH 10. JUNE 20 IS THE DAY FOR THIS EXAMPLE AND DATA RUNS FROM JUNE 20 UNTIL JULY 23.

COMPUTATIONS:

FOR EACH STATION THE NI SAMPLE CARDS ARE READ, ONE AT A TIME. A CHECK IS MADE ON THE TIME OF DAY THAT THE SAMPLE WAS TAKEN. IF OUTSIDE THE INTERVAL OF INTEREST THE SAMPLE IS DISREGARDED IN THE COMPUTATIONS WHICH FOLLOW. USING THE MONTH, DAY, AND HOUR THAT THE SAMPLE WAS TAKEN, THE TIDAL PHASE AT


```

18 WRITE(6,4) ISAT,NI
DO 10 I=1,NI
  READ(5,2,END=15) IMONTH, IDAY, TIME, DOX
C ***
C
C   OPTION OF DIFFERENT TIME INTERVAL IS AVAILABLE BY CHANGING
C   THE NEXT TWO CARDS.
C
C ***
C   IF(TIME- 455.) 10,10,21
21 IF(TIME- 905.) 22,10,10
22 NN=NN+1
   TIME=TIME/100.
  CALL TIDI2(IMONTH, IDAY, TIME, XPHASE, PHASE)
C ***
C
C   THE FOLLOWING CARD HAS THE SATURATION OXYGEN CONCENTRATION.
C   IF DIFFERENT DATA ARE BEING CONSIDERED, 8.0 PPM MUST BE
C   CHANGED TO THE APPROPRIATE VALUE.
C
C ***
C   ODX=8.0-DOX
  IPHASE=(PHASE+1)
  OD(IPHASE)=OD(IPHASE)+1.0
  XOD(IPHASE)=XOD(IPHASE)+ODX
  XXOD(IPHASE)=XXOD(IPHASE)+CDX*ODX
10 CONTINUE
DO 13 I=1,12
  IF(OD(I)-1.1) 13,13,14
14 XOD(I)=XOD(I)/OD(I)
  XXOD(I)=(XXOD(I)-XOD(I)*XOD(I)+OD(I))/(OD(I)-1.0)
  DELTA(I)= XOD(I)/XOD(I)
  DELTA=DELTA+DELTA(I)
13 WRITE(6,3) OD(I), XOD(I), XXOD(I), DELTA(I)
  DELTA=DELTA/12.

```



```

WRITE(6,5) DELTA ,NN,NI
11 CONTINUE
12 GO TO 16
15 WRITE(6,6) J
16 CONTINUE
17 STOP
END

```

STATION 1 WITH 1446 OBSERVATIONS

NO. IN SAMPLE=	25.	MEAN=2.074	VAR=0.401	DELTA=0.193
NO. IN SAMPLE=	22.	MEAN=1.964	VAR=0.416	DELTA=0.212
NO. IN SAMPLE=	25.	MEAN=1.796	VAR=0.274	DELTA=0.153
NO. IN SAMPLE=	22.	MEAN=1.847	VAR=0.368	DELTA=0.199
NO. IN SAMPLE=	22.	MEAN=1.696	VAR=0.362	DELTA=0.214
NO. IN SAMPLE=	20.	MEAN=1.796	VAR=0.429	DELTA=0.239
NO. IN SAMPLE=	23.	MEAN=2.016	VAR=0.610	DELTA=0.303
NO. IN SAMPLE=	21.	MEAN=2.253	VAR=0.831	DELTA=0.369
NO. IN SAMPLE=	22.	MEAN=2.555	VAR=0.530	DELTA=0.208
NO. IN SAMPLE=	23.	MEAN=2.534	VAR=0.319	DELTA=0.126
NO. IN SAMPLE=	22.	MEAN=2.407	VAR=0.494	DELTA=0.205
NO. IN SAMPLE=	23.	MEAN=2.077	VAR=0.548	DELTA=0.264

DELTA =0.2236 USING 270 OF THE 1446 TOTAL OBSERVATIONS

```

***** ESTUARY ANALYSIS PROGRAM *****
***** EXPLANATION OF OPERATIONS *****

INPUTS:

TIDE IS AN ARRAY OF TIDAL PHASE VALUES FROM 0.0 TO 6.555599
AT WHICH SOLUTIONS TO THE MODEL WERE DETERMINED
WHEN READ IN VALUES ARE NOT IN CORRECT ORDER.
SUBROUTINE GROOM MUST BE CALLED TO PREPARE TIDE AND
CORRESPONDING XX VALUES.

XX(1,P,T) IS AN ARRAY OF THESE SOLUTIONS FOR BOD. THE INDEX
P SIGNIFIES POSITION IN THE ESTUARY FOR SOME SPECIFIED
TIME IN THE TIDAL CYCLE. T SIGNIFIES THE TIME IN THE
TIDE FOR WHICH THIS WAS DETERMINED. THE ACTUAL T VALUES
ARE GIVEN IN THE ARRAY TIDE.

XX(2,P,T) IS AN ARRAY SIMILAR TO XX(1,P,T) EXCEPT THAT
IT IS A SOLUTION FOR QD AT P AND T.

XPHASE IS AN ARRAY OF TIMES AT WHICH HIGH TIDE OCCURED
AT SAMPLING STATIONS FOR A FIXED DAY DURING THE
SAMPLING PERIOD.

NPPOINT IS THE NUMBER OF VALUES OF ACTUAL DATA ABOUT TO BE
READ IN. POSIT IS THE POSITION AT WHICH THE MEASUREMENT
WAS TAKEN. IPPOSIT IS THE SAMPLING STATION NO.

OUTPUT:

1. BOTH SETS OF CONCENTRATION PROFILES
2. XVALUE, PREDICTED MEAN, CONFIDENCE LIMITS, ETC FOR EACH

```

EXPLANATION OF OPERATIONS

INPUTS:

TIDE IS AN ARRAY OF TIDAL PHASE VALUES FROM 0.0 TO 0.55555
AT WHICH SOLUTIONS TO THE MODEL WERE DETERMINED
WHEN READ IN VALUES ARE NOT IN CORRECT ORDER.
SUBROUTINE GROOM MUST BE CALLED TO PREPARE TIDE AND
CORRESPONDING XX VALUES

XX(1,P,T) IS AN ARRAY OF THESE SOLUTIONS FOR BOD. THE INDEX P SIGNIFIES POSITION IN THE ESTUARY FOR SOME SPECIFIED TIME IN THE TIGR4 CYCLE. T SIGNIFIES THE TIME IN THE TIDE FOR WHICH THIS WAS DETERMINED. THE ACTUAL T VALUES ARE GIVEN IN THE ARRAY TIME.

XX(2,P,T) IS AN ARRAY SIMILAR TO XX(1,P,T) EXCEPT THAT
IT IS A SOLUTION FOR Ω AT P AND T.

PHASE IS AN ARRAY OF TIDES AT WHICH HIGH TIDE OCCURRED
AT SAMPLING STATIONS FOR A FIXED DAY DURING THE
SAMPLING PERIOD.

POINT IS THE NUMBER OF VALUES OF ACTUAL DATA ABOUT TO BE READ IN. POSIT IS THE POSITION AT WHICH THE MEASUREMENT WAS TAKEN. IPOSIT IS THE SAMPLING STATION NO.

OUTPUT :

1. BOTH SETS OF CONCENTRATION PROFILES
2. XVALUE, PREDICTED MEAN, CONFIDENCE LIMITS, ETC FOR EACH


```

C C C INDIVIDUAL OBSERVED DATA POINT.
C C C 3. SUMMARY OF DATA OUTSIDE LIMITS FOR EACH STATION.
C C C *****
C C C SUMMARY OF COMPUTATIONS:
C C C
C C C TIDE AND XX ARE READ IN. TIDE VALUES ARE CONVERTED FROM TIDE
C C C NO., 24.273, CYCLES TO PHASE VALUES, 0.273. THEN TIDE
C C C IS REARRANGED IN STRICTLY ASCENDING ORDER. XX VALUES
C C C ARE ALSO REARRANGED TO LINE UP WITH THEIR CORRESPONDING
C C C TIDE VALUES. CONCENTRATION PROFILES ARE DETERMINED
C C C THROUGH THE ESTUARY FOR TIDAL PHASES OF 0.0, 0.25,
C C C 0.50, AND 0.75 AND PROFILES THROUGH TIDAL CYCLE FOR
C C C EACH STATION OF INTEREST. THEN ACTUAL DATA IS READ IN
C C C BY STATIONS. FOR EACH OBSERVED VALUE, A PREDICTED MEAN
C C C AND AN ALPHA PERCENT POISSON CONFIDENCE LIMITS ARE
C C C DETERMINED. THE NUMBER OF VALUES WHICH FALL OUTSIDE OF
C C C THE CONFIDENCE INTERVAL FOR EACH STATION IS TABULATED.
C C C *****
C C C SUBROUTINES LENGTH AND TIMEX CALCULATE PROFILES THROUGH THE
C C C ESTUARY AT DIFFERENT TIDAL PHASES AND THROUGH THE TIDAL
C C C CYCLE FOR EACH SAMPLING STATION, RESPECTIVELY.
C C C
C C C XPOSIT IS AN ARRAY OF POSITIONS, IN MILES, AT WHICH XX
C C C VALUES ARE GIVEN BY THE DIFFERENTIAL EQUATIONS PROGRAM.
C C C THESE CORRESPOND TO THE P INDEX OF XX.
C C C *****
C C C ORDER AND FORMAT OF INPUT:
C C C
C C C 1. XX AND TIDE. FORMAT FIXED BY OUTPUT FORMAT OF THE

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```

C      IPOSIT = SAMPLING STATION NUMBER
C      PCSIT  = POSITION ON ESTUARY, IN MILES, WHERE SAMPLING
C      STATION IS LOCATED.
C*****
      READ(5,2,END=13) NPOINT,IPOSIT, POSIT
      2 FORMAT(2I5, F10.4)
      IF(NPOINT) 14,14,98
      98 WRITE(6,80) JJ
      80 FORMAT('RESULTS OF STATION NO.',I3//87X'NO. OBS./3X,'OBSERVED',6X
      1,'PREDICTED',10X,'LOWER',10X,'UPPER',20X,'NO. OBS.',3X,'ACTUALLY',
      23X,'NO. OUTSIDE',4X,2('VALUE',10X),2X,2('LIMIT',10X),'PHASE',3X,
      3,'CONSIDERED',5X,'KEPT',7X,'LIMITS')
      DO 11 I=1,NPOINT
C*****
C      C      READING IN ACTUAL DATA VALUES
C      C*****
      READ(5,3,END=13) IMONTH, IDAY, TIME, XVALUE
      3 FORMAT(22X,I2,I1X,I2,I1X,F5.0,23X,F5.3)
C*****
C      DISCARDING DATA NOT TAKEN BETWEEN 5 AND 9 AM TO PREVENT
C      DISTORTION DUE TO WITHIN DAYS VARIATION CAUSED BY PHOTOSYNTHESIS
C*****
      IF(TIME-455.) 11,11,15
      15 IF(TIME-905.) 16,11,11
      16 IPOINT=IPOINT+1
      XVALUE=XVALUE+XVALUE
      CALL TIDAL(IMONTH, IDAY, TIME, XPHASE(IPOSIT), PHASE)
      CALL PREDIC(XX, NKEEP, IPOSIT, TIDE, PHASE, XMEAN)
      CALL LIMITJ(XMEAN, XLIM1, XLIM2, IPOSIT)
      CALL COUNT( XVALUE, XLIM1, XLIM2, ICOUNT)

```

```

ITOTAL=ITOTAL+ICOUNT
WRITE(6,6) XVALUE,XMEAN,XLIM1,XLIM2,PHASE,I,IPOINT,ITOTAL
6  FORMAT(1X,5(F10.4,5X),15,6X,15,8X,15)
11 CONTINUE
12 WRITE(6,4) ITOTAL, IPOINT
4  FORMAT(11,'THERE WERE ',I3,' DATA POINTS OUTSIDE OF CONFIDENCE
1 LIMITS OUT OF ',I4,' OBSERVATIONS')
14 CONTINUE
13 STOP
END

```

OD VALUES THRU ESTUARY FOR FOUR TIDAL PHASES

1.4 946	0.9010	1.0115	1.0394
1.4 957	0.8463	1.0247	1.0007
1.4 973	0.8737	1.0395	1.1218
1.4 975	0.8253	1.0541	1.1487
1.4 987	0.8456	1.0743	1.2132
1.4 987	0.8456	1.0943	1.2433
1.4 998	0.9267	1.1140	1.3131
1.4 998	0.9267	1.1395	1.3441
1.4 998	0.9267	1.1648	1.4144
1.4 998	0.9267	1.1918	1.4702
1.4 998	0.9267	1.2207	1.5251
1.4 998	0.9267	1.2514	1.5807
1.4 998	0.9267	1.2840	1.6373
1.4 998	0.9267	1.3185	1.6945
1.4 998	0.9267	1.3550	1.7520
1.4 998	0.9267	1.3935	1.8099
1.4 998	0.9267	1.4340	1.8679
1.4 998	0.9267	1.4767	1.9254
1.4 998	0.9267	1.5215	1.9827
1.4 998	0.9267	1.5686	2.0393
1.4 998	0.9267	1.6179	2.0952
1.4 998	0.9267	1.6694	2.1502
1.4 998	0.9267	1.7234	2.2047
1.4 998	0.9267	1.7800	2.2590
1.4 998	0.9267	1.8387	2.3140
1.4 998	0.9267	1.8997	2.3710
1.4 998	0.9267	1.9626	2.4314
1.4 998	0.9267	2.0272	2.4977
1.4 998	0.9267	2.0929	2.5713
1.4 998	0.9267	2.1590	2.6440
1.4 998	0.9267	2.2264	2.7164
1.4 998	0.9267	2.2942	2.7883
1.4 998	0.9267	2.3622	2.8593
1.4 998	0.9267	2.4304	2.9293
1.4 998	0.9267	2.4987	3.0000
1.4 998	0.9267	2.5672	3.0714
1.4 998	0.9267	2.6358	3.1434
1.4 998	0.9267	2.7045	3.2159
1.4 998	0.9267	2.7732	3.2889
1.4 998	0.9267	2.8420	3.3624
1.4 998	0.9267	2.9108	3.4364
1.4 998	0.9267	2.9796	3.5109
1.4 998	0.9267	3.0484	3.5859
1.4 998	0.9267	3.1172	3.6614
1.4 998	0.9267	3.1860	3.7374
1.4 998	0.9267	3.2548	3.8139
1.4 998	0.9267	3.3236	3.8909
1.4 998	0.9267	3.3924	3.9684
1.4 998	0.9267	3.4612	4.0464
1.4 998	0.9267	3.5300	4.1249
1.4 998	0.9267	3.5988	4.2039
1.4 998	0.9267	3.6676	4.2834
1.4 998	0.9267	3.7364	4.3634
1.4 998	0.9267	3.8052	4.4439
1.4 998	0.9267	3.8740	4.5249
1.4 998	0.9267	3.9428	4.6064
1.4 998	0.9267	4.0116	4.6884
1.4 998	0.9267	4.0804	4.7709
1.4 998	0.9267	4.1492	4.8539
1.4 998	0.9267	4.2180	4.9374
1.4 998	0.9267	4.2868	5.0214
1.4 998	0.9267	4.3556	5.1059
1.4 998	0.9267	4.4244	5.1909
1.4 998	0.9267	4.4932	5.2764
1.4 998	0.9267	4.5620	5.3624
1.4 998	0.9267	4.6308	5.4489
1.4 998	0.9267	4.6996	5.5359
1.4 998	0.9267	4.7684	5.6234
1.4 998	0.9267	4.8372	5.7114
1.4 998	0.9267	4.9060	5.8004
1.4 998	0.9267	4.9748	5.8904
1.4 998	0.9267	5.0436	5.9814
1.4 998	0.9267	5.1124	6.0734
1.4 998	0.9267	5.1812	6.1664
1.4 998	0.9267	5.2500	6.2604
1.4 998	0.9267	5.3188	6.3554
1.4 998	0.9267	5.3876	6.4514
1.4 998	0.9267	5.4564	6.5484
1.4 998	0.9267	5.5252	6.6464
1.4 998	0.9267	5.5940	6.7454
1.4 998	0.9267	5.6628	6.8454
1.4 998	0.9267	5.7316	6.9464
1.4 998	0.9267	5.8004	7.0484
1.4 998	0.9267	5.8692	7.1514
1.4 998	0.9267	5.9380	7.2554
1.4 998	0.9267	6.0068	7.3604
1.4 998	0.9267	6.0756	7.4664
1.4 998	0.9267	6.1444	7.5734
1.4 998	0.9267	6.2132	7.6814
1.4 998	0.9267	6.2820	7.7904
1.4 998	0.9267	6.3508	7.9004
1.4 998	0.9267	6.4196	8.0114
1.4 998	0.9267	6.4884	8.1234
1.4 998	0.9267	6.5572	8.2364
1.4 998	0.9267	6.6260	8.3504
1.4 998	0.9267	6.6948	8.4654
1.4 998	0.9267	6.7636	8.5814
1.4 998	0.9267	6.8324	8.6984
1.4 998	0.9267	6.9012	8.8164
1.4 998	0.9267	6.9700	8.9354
1.4 998	0.9267	7.0388	9.0554
1.4 998	0.9267	7.1076	9.1764
1.4 998	0.9267	7.1764	9.2984
1.4 998	0.9267	7.2452	9.4214
1.4 998	0.9267	7.3140	9.5454
1.4 998	0.9267	7.3828	9.6704
1.4 998	0.9267	7.4516	9.7964
1.4 998	0.9267	7.5204	9.9234
1.4 998	0.9267	7.5892	10.0514
1.4 998	0.9267	7.6580	10.1804
1.4 998	0.9267	7.7268	10.3104
1.4 998	0.9267	7.7956	10.4414
1.4 998	0.9267	7.8644	10.5734
1.4 998	0.9267	7.9332	10.7064
1.4 998	0.9267	8.0020	10.8404
1.4 998	0.9267	8.0708	10.9754
1.4 998	0.9267	8.1396	11.1114
1.4 998	0.9267	8.2084	11.2484
1.4 998	0.9267	8.2772	11.3864
1.4 998	0.9267	8.3460	11.5254
1.4 998	0.9267	8.4148	11.6654
1.4 998	0.9267	8.4836	11.8064
1.4 998	0.9267	8.5524	11.9484
1.4 998	0.9267	8.6212	12.0914
1.4 998	0.9267	8.6900	12.2354
1.4 998	0.9267	8.7588	12.3804
1.4 998	0.9267	8.8276	12.5264
1.4 998	0.9267	8.8964	12.6734
1.4 998	0.9267	8.9652	12.8214
1.4 998	0.9267	9.0340	12.9704
1.4 998	0.9267	9.1028	13.1204
1.4 998	0.9267	9.1716	13.2714
1.4 998	0.9267	9.2404	13.4234
1.4 998	0.9267	9.3092	13.5764
1.4 998	0.9267	9.3780	13.7304
1.4 998	0.9267	9.4468	13.8854
1.4 998	0.9267	9.5156	14.0414
1.4 998	0.9267	9.5844	14.1984
1.4 998	0.9267	9.6532	14.3564
1.4 998	0.9267	9.7220	14.5154
1.4 998	0.9267	9.7908	14.6754
1.4 998	0.9267	9.8596	14.8364
1.4 998	0.9267	9.9284	15.0004
1.4 998	0.9267	10.0000	15.1664

LISTING OF CD VALUES THRU TIDAL PHASE FOR THREE STAT

2.5432	6.5240	6.4246
2.5410	6.5318	6.4420
2.5383	6.5357	6.4658
2.5355	6.5357	6.4967
2.5328	6.5322	6.5278
2.5298	6.5291	6.5692
2.5270	6.5134	6.6136
2.5246	6.4975	6.6612
2.5226	6.4772	6.7121
2.5200	6.4534	6.7645
2.5177	6.4242	6.8137
2.5151	6.3893	6.8701
2.5126	6.3492	6.9268
2.5100	6.3030	6.9840
2.5073	6.2497	7.0416
2.5041	6.1883	7.0987
2.5015	6.1174	7.1542
2.4989	6.0347	7.2089
2.4963	5.9414	7.2646
2.4937	5.8385	7.3204
2.4914	5.7271	7.3780
2.4890	5.6058	7.4361
2.4865	5.4977	7.4913
2.4839	5.3843	7.5457
2.4815	5.2674	7.6003
2.4790	5.1490	7.6549
2.4762	4.9813	7.7123
2.4733	4.8543	7.7625
2.4706	4.7342	7.8185
2.4679	4.6134	7.8710
2.4651	4.5017	7.9296
2.4623	4.3827	7.9853
2.4596	4.2690	8.0374
2.4568	4.1509	8.0985
2.4541	4.0385	8.1579
2.4513	3.9240	8.2169
2.4485	3.8015	8.2752
2.4457	3.6847	8.3333
2.4429	3.5627	8.3922
2.4401	3.4437	8.4520
2.4373	3.3217	8.5127
2.4345	3.1971	8.5747
2.4317	3.0741	8.6390
2.4289	2.9510	8.7012
2.4261	2.8298	8.7643
2.4233	2.7085	8.8286
2.4205	2.5865	8.8933
2.4177	2.4643	8.9590
2.4149	2.3417	9.0268
2.4121	2.2192	9.0953
2.4093	2.0967	9.1646
2.4065	1.9741	9.2346
2.4037	1.8515	9.3053
2.4009	1.7289	9.3768
2.4081	1.6063	9.4492
2.4053	1.4837	9.5223
2.4025	1.3611	9.5953
2.4097	1.2385	9.6683
2.4069	1.1159	9.7413
2.4041	0.9933	9.8143
2.4013	0.8707	9.8873
2.3985	0.7481	9.9603
2.3957	0.6255	10.0333
2.3929	0.5029	10.1063
2.3901	0.3803	10.1793
2.3873	0.2577	10.2523
2.3845	0.1351	10.3253
2.3817	0.0125	10.3983
2.3789	-0.1101	10.4713
2.3761	-0.2325	10.5443
2.3733	-0.3549	10.6173
2.3705	-0.4773	10.6903
2.3677	-0.5997	10.7633
2.3649	-0.7221	10.8363
2.3621	-0.8445	10.9093
2.3593	-0.9669	10.9823
2.3565	-1.0893	11.0553
2.3537	-1.2117	11.1283
2.3509	-1.3341	11.2013
2.3481	-1.4565	11.2743
2.3453	-1.5789	11.3473
2.3425	-1.7013	11.4203
2.3397	-1.8237	11.4933
2.3369	-1.9461	11.5663
2.3341	-2.0685	11.6393
2.3313	-2.1909	11.7123
2.3285	-2.3133	11.7853
2.3257	-2.4357	11.8583
2.3229	-2.5581	11.9313
2.3201	-2.6805	12.0043
2.3173	-2.8029	12.0773
2.3145	-2.9253	12.1503
2.3117	-3.0477	12.2233
2.3089	-3.1701	12.2963
2.3061	-3.2925	12.3693
2.3033	-3.4149	12.4423
2.3005	-3.5373	12.5153
2.2977	-3.6597	12.5883
2.2949	-3.7821	12.6613
2.2921	-3.9045	12.7343
2.2893	-4.0269	12.8073
2.2865	-4.1493	12.8803
2.2837	-4.2717	12.9533
2.2809	-4.3941	13.0263
2.2781	-4.5165	13.0993
2.2753	-4.6389	13.1723
2.2725	-4.7613	13.2453
2.2697	-4.8837	13.3183
2.2669	-5.0061	13.3913
2.2641	-5.1285	13.4643
2.2613	-5.2509	13.5373
2.2585	-5.3733	13.6103
2.2557	-5.4957	13.6833
2.2529	-5.6181	13.7563
2.2501	-5.7405	13.8293
2.2473	-5.8629	13.9023
2.2445	-5.9853	13.9753
2.2417	-6.1077	14.0483
2.2389	-6.2301	14.1213
2.2361	-6.3525	14.1943
2.2333	-6.4749	14.2673
2.2305	-6.5973	14.3403
2.2277	-6.7197	14.4133
2.2249	-6.8421	14.4863
2.2221	-6.9645	14.5593
2.2193	-7.0869	14.6323
2.2165	-7.2093	14.7053
2.2137	-7.3317	14.7783
2.2109	-7.4541	14.8513
2.2081	-7.5765	14.9243
2.2053	-7.6989	15.0000


```

5 CONCENTRATION SHOWN IN THE TABLE. TIDAL PHASE INCREASES DOWN THE PAGE
6 WITH PHASE=0.0 FOR HIGH TIDE. //55X, 'ALPHA-LEVEL', / 6X,
7 PHASE 0.95 0.90 0.85 0.80 0.75 0.70 0.65 0.60 0.55 0.50
8 0.45 0.40 0.35 0.30 0.25 0.20 0.15 0.10 0.05 /
9 6X, 124( ' ' ) /
DO 11 I=1, 101
PHASE=0.01*FLOAT(I-1)
CALL PREXXX(X, NKEEP, IPOSIT, TIDE, PHASE, XMEAN)
CALL LIMXXX(XMEAN, PHASE, IVECT, IPOSIT)
DO 13 J=1, 101
13 LINE(I, J)=BLK
DO 14 J=1, 11
KK=(J-1)*10+1
14 LINE(I, KK)=DOT
LINE(I, IVECT( 2 ))=NINE
LINE(I, IVECT( 4 ))=EIGHT
LINE(I, IVECT( 6 ))=SEVEN
LINE(I, IVECT(18 ))=ONE
LINE(I, IVECT(16 ))=TWO
LINE(I, IVECT(14 ))=THREE
LINE(I, IVECT(10 ))=STAR
11 CONTINUE
WRITE(6, 201) IPOSIT
201 FORMAT('1', 35X, 'GRAPHED SUMMARY OF ABOVE TABLE FOR STATION', I3//
140X, 'OXYGEN DEFICIT CONCENTRATION, PPM, ' / PHASE 0.0, 7X,
2*1.0, 7X, 2.0, 7X, 3.0, 7X, 4.0, 7X, 5.0, 7X, 6.0, 7X, 7.0, 7X,
3*8.0, 7X, 9.0, 6X, 10.0 / 12X, 101( ' ' ))
DO 20 I=1, 101
X=0.01*FLOAT(I-1)
20 WRITE(6, 4) X, (LINE(I, J), J=1, 101)
WRITE(6, 202)
202 FORMAT( 12X, 101( ' ' ) / PHASE 0.0, 7X, 1.0, 7X, 2.0, 7X, 3.0,
27X, 4.0, 7X, 5.0, 7X, 6.0, 7X, 7.0, 7X, 8.0, 7X, 9.0, 6X, 10.0 /
340X, 'OXYGEN DEFICIT CONCENTRATION, PPM, ' )
GO TO 12

```

99 STOP
END

SAMPLE DATA FOR LIMITS PROGRAM. OUTPUT FROM DIFFERENTIAL EQUATIONS
PROGRAM HAS BEEN DELETED

* 123456789

1
2
3

[illegible]244

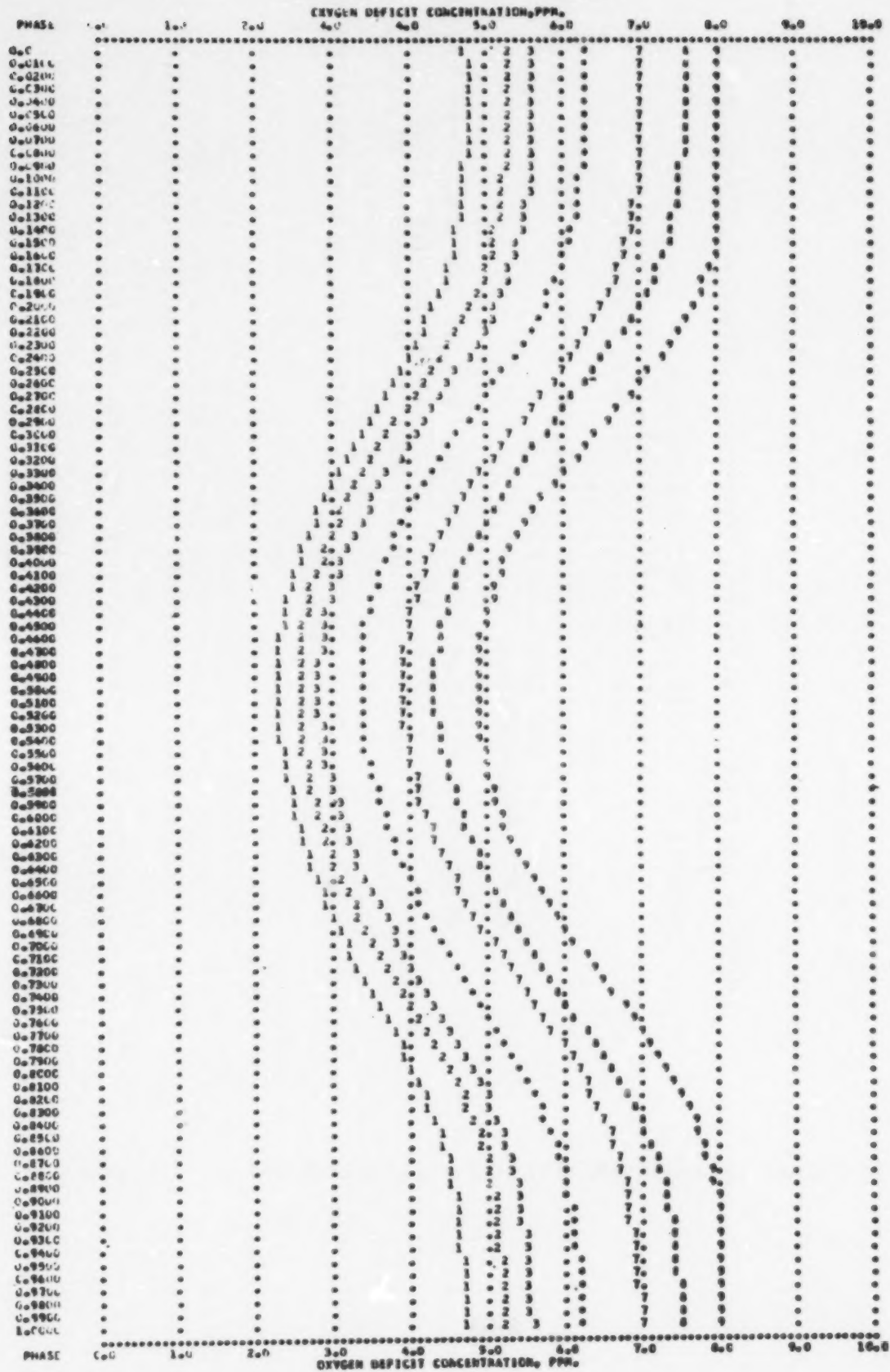
GRAPHED SUMMARY OF ABOVE TABLE FOR STATION 1

PHASE	0.0	OXYGEN DEFICIT CONCENTRATION, PPM									
		1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
0.0C	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.0100	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.0200	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.0300	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.0400	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.0500	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.0600	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.0700	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.0800	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.0900	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.1000	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.1100	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.1200	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.1300	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.1400	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.1500	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.1600	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.1700	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.1800	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.1900	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.2000	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.2100	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.2200	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.2300	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.2400	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.2500	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.2600	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.2700	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.2800	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.2900	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.3000	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.3100	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.3200	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.3300	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.3400	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.3500	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.3600	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.3700	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.3800	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.3900	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.4000	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.4100	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.4200	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.4300	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.4400	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.4500	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.4600	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.4700	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.4800	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.4900	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.5000	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.5100	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.5200	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.5300	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.5400	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.5500	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.5600	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.5700	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.5800	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.5900	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.6000	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.6100	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.6200	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.6300	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.6400	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.6500	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.6600	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.6700	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.6800	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.6900	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.7000	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.7100	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.7200	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.7300	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.7400	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.7500	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.7600	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.7700	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.7800	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.7900	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.8000	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.8100	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.8200	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.8300	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.8400	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.8500	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.8600	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.8700	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.8800	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.8900	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.9000	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.9100	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.9200	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.9300	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.9400	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.9500	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.9600	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.9700	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.9800	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
0.9900	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
1.0000	.	1.2 3.	.	7.8	9.	.	.	.	.	.	.
PHASE	0.0	1.0	2.0	OXYGEN DEFICIT CONCENTRATION, PPM							
	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0

THE CALCULATEDLY WITHIN THE TABLE ARE ONE-SIDED CONFIDENCE INTERVALS FOR STATISTIC Z. THE CALCULATEDLY WITHIN THE TABLE ARE ONE-SIDED CONFIDENCE INTERVALS FOR CYTOSIN DEFICIT AS FUNCTIONS OF TIDAL PHASE AND CONCENTRATION/DEPTH LEVELS. THE STATISTICAL ALPHA OF EACH CYTOSIN DEFICIT OBSERVATION WAS ADJUSTED TO FALL BELOW THE 0.05 CONCENTRATION/DEPTH LEVELS SHOWN IN THE TABLE. TIDAL PHASE INCREASES DOWN THE PAGE WITH PHASE=0 FOR HIGH TIDE.

[illegible]

GRAPHED SUMMARY OF ABOVE TABLE FOR STATION 2



```

C*****
C      RIVER DELTA PROGRAM
C*****
C      INPUTS: DATA CARDS WITH THE FOLLOWING DATA:N,I,ITIME,IMINS,
C              X AND Y
C      WHERE: N=A POSITIVE INTEGER NUMBER
C              I=STATION NO.,(INTEGER).
C              ITIME=HOUR OF DAY,(0 TO 24),(INTEGER).
C              IMINS=MINS,(INTEGER).
C              X=DISSOLVED OXYGEN CONCENTRATION IN PPM.
C              Y= BOD CONC. IN PPM.
C      FORMAT(4I5,2F10.4)
C*****
C      NOTE: THE PROGRAM IS CURRENTLY SET UP FOR THE CHIO RIVER
C      USING A TOTAL OF SEVEN STATIONS RUNNING FROM 2 TO
C      8. THE PROGRAM WOULD HAVE TO BE CHANGED TO RUN
C      OTHER DATA. SPECIFICALLY THE INPUT FORMAT, THE DO
C      LOOP LIMITS, REMOVE THE X=(X1+X2)/2 AND Y=(Y1+Y2)/2
C      CARDS AND DIMENSION.
C*****
C      OPERATIONS:
C      THE PROGRAM CATEGORIZES ACCORDING TO TIME OF DAY AND
C      STATION NUMBER AND THEN CALCULATES DELTAS IN EACH
C      SUBDIVISION. THE NUMBER OF SAMPLES FALLING INTO EACH
C      CELL, THE DELTA IN EACH CELL, THE AVERAGE DELTAS FOR
C      STATIONS AND TIME OF DAY AND THE OVERALL DELTA ARE
C      PRINTED.
C*****
C      SUBROUTINES REQUIRED:      NONE
C*****
C      DIMENSION SUM(2,8,8 ),SS(2,8,8 ),ICOUNT(8,8 ),DELTA(2,8,8 ),D(2,8)
C*****

```

```

DO 10 I=2,8
DO 10 J=1,8
ICOUNT(I,J)=0
DO 10 K=1,2
SUM(K,I,J)=0.0
D(K,I)=0.0
10 SS(K,I,J)=0.0
C
C
C THE FOLLOWING READ AND FORMAT CARDS MUST BE CHANGED IF CHIO
C RIVER, MARKLAND POOL, DATA IS NOT BEING CONSIDERED.
C FOR NON-OHIO DATA, THE PRESENT READ SHOULD BE REPLACED BY
C THE FOLLOWING:
C 11 READ(5,1,END=99) N,I,ITIME,IMINS,X,Y
C
C
C 11 READ(5,1,END=99) N,I,ITIME,IMINS,X1,X2,Y1,Y2
C 1 FORMAT(2I5,20X,2I5,10X,4F5.1)
C
C THE NEXT TWO CARDS MUST BE REMOVED FOR NON-OHIO DATA.
C
C
C X=(X1+X2)/2.0
C Y=(Y1+Y2)/2.0
C IF(N) 9,9,19
19 X=8.25-X
J=IFIX((FLOAT(ITIME)*100.0+FLOAT(IMINS)*100.0/60.0+50.0)/300.0)
IF(J) 8,8,7
8 J=8
7 SUM(1,I,J)=SUM(1,I,J)+X
SS(1,I,J)=SS(1,I,J)+X*X
SUM(2,I,J)=SUM(2,I,J)+Y
SS(2,I,J)=SS(2,I,J)+Y*Y
ICOUNT(I,J)=ICOUNT(I,J)+1

```



```

GO TO 11
9 WRITE(6,63)
63 FORMAT('1TABLE OF SAMPLES FALLING INTO EACH SUBGROUP.'/0TABLE IS
1ARRANGED WITH THE TIME OF DAY CLASSES IN.'/0 COLUMNS ACROSS THE PAG
2E WHILE THE STATIONS ARE.'/0 ARRANGED IN ROWS DOWN THE PAGE.')
DO 12 I=2,8
WRITE(6,4) (ICOUNT(I,J),J=1,8)
4 FORMAT('0', 8I6)
DO 12 J=1,8
IF(ICOUNT(I,J)-1) 13,13,14
14 DO 15 K=1,2
Z=FLOAT(ICOUNT(I,J))
XMEAN=SUM(K,I,J)/Z
VAR=(SS(K,I,J)-SUM(K,I,J)*XMEAN)/(Z-1.0)
15 DELTA(K,I,J)=VAR/XMEAN
GO TO 12
13 DELTA(1,I,J)=0.0
DELTA(2,I,J)=0.0
12 CONTINUE
DO 18 K=1,2
1F(K-1) 93,93,94
93 WRITE(6,91)
91 FORMAT('1',10X,'TABLE OF OD DELTA VALUES.'/0THE TABLE HAS TIME CL
ASSES IN THE COLUMNS ACROSS THE PAGE WITH THE STATIONS IN THE ROWS
2 DOWN THE PAGE.'/0 THE LAST COLUMN IS STATION AVERAGES, THE LAST R
3OW IS TIME CLASS AVERAGES, AND THE BOTTOM RIGHT HAND.'/0 ELEMENT IS
4 THE OVERALL AVERAGE OD DELTA.')
GO TO 95
94 WRITE(6,92)
92 FORMAT('1',10X,'TABLE OF BOD DELTA VALUES.'/0THE TABLE HAS TIME C
LASSES IN THE COLUMNS ACROSS THE PAGE WITH THE STATIONS IN THE ROW
2S DOWN THE PAGE.'/0 THE LAST COLUMN IS STATION AVERAGES, THE LAST
3ROW IS TIME CLASS AVERAGES, AND THE BOTTOM RIGHT HAND.'/0 ELEMENT I
4S THE OVERALL AVERAGE BOD DELTA.')
95 DD=0.0

```

```

DO 17 I=2,8
DO 16 J=1,8
16 D(K,I)=D(K,I)+DELTA(K,I,J)
D(K,I)=D(K,I)/8.0
DD=DD+D(K,I)
17 WRITE(6,2) I, (DELTA(K,I,J),J=1,8),D(K,I)
2 FORMAT('0',I5,10F10.5)
DO 22 J=1,8
22 SUM(1,1,J)=0.0
DO 21 J=1,8
DO 20 I=2,8
20 SUM(1,1,J)=SUM(1,1,J)+DELTA(K,I,J)
21 SUM(1,1,J)=SUM(1,1,J)/7.0
DD=DD/7
WRITE(6,96) (SUM(1,1,J),J=1,8),DD
96 FORMAT('0',5X,9F10.5)
18 CONTINUE
99 STOP
END

```

TABLE OF SAMPLES FALLING INTO EACH SUBGROUP.

TABLE IS ARRANGED WITH THE TIME OF DAY CLASSES IN COLUMNS ACROSS THE PAGE WHILE THE STATIONS ARE ARRANGED IN ROWS DOWN THE PAGE.

17	16	17	17	17	17	17	17
17	16	17	17	17	17	17	17
17	16	17	17	17	17	17	17
17	16	17	17	17	17	17	17
17	16	17	17	17	17	17	17
17	16	17	17	17	17	17	17
17	17	16	17	17	17	17	17

TABLE OF OO DELTA VALUES

THE TABLE HAS TIME CLASSES IN THE COLUMNS ACROSS THE PAGE WITH THE STATIONS IN THE ROWS DOWN THE PAGE. THE LAST COLUMN IS STATION AVERAGES, THE LAST ROW IS TIME CLASS AVERAGES, AND THE BOTTOM RIGHT HAND ELEMENT IS THE OVERALL AVERAGE OO DELTA.

2	0.10684	0.13987	0.10159	0.20556	0.09897	0.10232	0.10422	0.14223	0.12520
3	0.11227	0.15200	0.26731	0.30881	0.24161	0.26792	0.15555	0.10246	0.20099
4	0.20586	0.18348	0.28394	0.24677	0.26886	0.22250	0.18215	0.10362	0.21215
5	0.25796	0.20405	0.21712	0.18103	0.11832	0.20020	0.25466	0.27930	0.21408
6	0.24212	0.18482	0.20211	0.19517	0.19194	0.22502	0.19220	0.22329	0.20709
7	0.13038	0.09461	0.11483	0.09758	0.12373	0.19821	0.17734	0.10243	0.12989
8	0.08673	0.08389	0.09721	0.09997	0.10207	0.13370	0.14000	0.09736	0.10512
	0.16317	0.14896	0.18344	0.19070	0.16364	0.19284	0.17230	0.15010	0.17064

TABLE OF BOD DELTA VALUES

THE TABLE HAS TIME CLASSES IN THE COLUMNS ACROSS THE PAGE WITH THE STATIONS IN THE ROWS DOWN THE PAGE. THE LAST COLUMN IS STATION AVERAGES, THE LAST ROW IS TIME CLASS AVERAGES, AND THE BOTTOM RIGHT HAND ELEMENT IS THE OVERALL AVERAGE BOD DELTA.

2	0.04873	0.08523	0.12389	0.12389	0.07581	0.04478	0.06160	0.03022	0.07427
3	0.13983	0.10719	0.09664	0.14282	0.13786	0.13515	0.17621	0.14521	0.13512
4	0.19956	0.17195	0.17117	0.15249	0.14747	0.21308	0.15931	0.11106	0.16576
5	0.06374	0.18122	0.34519	0.25478	0.14325	0.15689	0.09484	0.07876	0.16483
6	0.08953	0.23712	0.23592	0.30691	0.13289	0.13105	0.08705	0.07698	0.16218
7	0.03149	0.04110	0.08868	0.06859	0.06181	0.08737	0.06656	0.08891	0.06681
8	0.03547	0.04855	0.05641	0.06223	0.03887	0.07322	0.05454	0.06298	0.05403
	0.08691	0.12462	0.15970	0.15882	0.10542	0.12022	0.10002	0.08488	0.11757

```

C*****
C RIVER ANALYSIS PROGRAM
C*****
C
C INPUTS:
C   1. PRED. PREDICTED MEAN CONCENTRATIONS AT EACH
C     SAMPLING STATION. FORMAT(8F10.4).
C   2. HEADER CARD FOR EACH SAMPLING STATION. STATION
C     NO. AND NO. OF OBSERVATIONS TAKEN.
C     FORMAT(2I5).
C   3. OBSVATION CARDS. XVALUE. FORMAT(F10.4)
C
C COMPUTATIONS:
C   1. THE PREDICTED MEAN AT EACH STATION IS
C     TAKEN AND USED IN DETERMINING ALPHA &
C     CONFIDENCE LIMITS ABOUT ITSELF.
C   2. THE OBSERVATIONS ARE READ AND COMPARED
C     WITH CONFIDENCE LIMITS.
C   3. THE NO. OF OBSERVATIONS OUTSIDE OF CONF-
C     IDENCE LIMITS FOR EACH STATION IS
C     DETERMINED AND READ.
C
C SUBROUTINES USED:
C   1. LIMRIV
C   2. COUNT
C
C*****
C DIMENSION PRED(6),LIMITX(2,6)
C REAL LIMITX
C READ(5,5) (PRED(I),I=1,6)
C 5 FORMAT(8F10.4)
C DO 10 I=1,6
C 10 CALL LIMRIV(PRED(I),LIMITX(1,I),LIMITX(2,I),I)
C 11 READ(5,2,END=99) ISTAT,NI
C 2 FORMAT(2I5)
C ITOTAL=0
C IF(NI) 11,11,12

```



```

12 J=ISTAT-2
   WRITE(6,8) ISTAT
   6 FORMAT(11 RESULTS FOR STATION NO.,13// SAMPLE.,9X,LOWER.,7X,
1 OBSERVED.,10X,UPPER.,3X,NO.OUTSIDE.,3X,PREDICTED.,3X,NO.,10X
2, LIMIT., 8X,VALUE.,12X,LIMIT.,5X,LIMITS.,7X,VALUE//)
   DO 13 I=1,NI
     READ(5,1,END=99) N,K,ITIME,IMINS,X1,X2,Y1,Y2
     1 FORMAT(2I5,20X,2I5,10X,4F5.1)
C ***
C THE NEXT TWO CARDS SHOULD BE INTERCHANGED IF BOD DELTAS ARE TO
C BE CALCULATED.
C ***
XVALUE=(Y1+Y2)/2.0
XVALUE=8.25-(X1+X2)/2.0
CALL COUNT(XVALUE,LIMITX(1,J),LIMITX(2,J),ICOUNT)
ITOTAL=ITOTAL+ICOUNT
IF(ICOUNT) 13,13,14
14 WRITE(6,9) J,LIMITX(1,J), XVALUE,LIMITX(2,J),ITOTAL ,PRED(J)
   9 FORMAT(11,15,3(5X,F10.4),5X,15,5X,F10.4)
13 CONTINUE
   WRITE(6,3) ISTAT,ITOTAL,NI
   3 FORMAT(10,10X,15// STATION SUMMARY// STATION NO.,10X,15// NO. OUTS
11IDE LIMITS 1,15// TOTAL NO. OF OBS. 1,15)
   GO 11J-11
99 STOP
   END

```

RESULTS FOR STATION NO. 3

SAMPLE NO.	LOWER LIMIT	OBSERVED VALUE	UPPER LIMIT	NO. OUTSIDE LIMITS	PREDICTED VALUE
4	2.7117	1.7000	3.9269	1	3.4000
10	2.7117	2.7000	3.9269	2	3.4000
12	2.7117	2.4000	3.9269	3	3.4000
13	2.7117	2.5000	3.9269	4	3.4000
20	2.7117	2.3000	3.9269	5	3.4000
22	2.7117	4.4000	3.9269	6	3.4000
23	2.7117	4.5500	3.9269	7	3.4000
26	2.7117	2.2500	3.9269	8	3.4000
27	2.7117	2.2500	3.9269	9	3.4000
28	2.7117	2.1500	3.9269	10	3.4000
29	2.7117	2.2000	3.9269	11	3.4000
30	2.7117	2.5000	3.9269	12	3.4000
32	2.7117	2.6500	3.9269	13	3.4000
34	2.7117	2.5000	3.9269	14	3.4000
35	2.7117	2.5000	3.9269	15	3.4000
36	2.7117	1.7000	3.9269	16	3.4000
37	2.7117	1.8000	3.9269	17	3.4000
38	2.7117	2.5000	3.9269	18	3.4000
39	2.7117	2.6000	3.9269	19	3.4000
50	2.7117	1.7000	3.9269	20	3.4000
51	2.7117	2.2000	3.9269	21	3.4000
52	2.7117	1.8500	3.9269	22	3.4000
53	2.7117	2.3000	3.9269	23	3.4000
57	2.7117	4.2000	3.9269	24	3.4000
58	2.7117	4.4000	3.9269	25	3.4000
61	2.7117	4.3000	3.9269	26	3.4000
62	2.7117	4.4500	3.9269	27	3.4000
63	2.7117	4.6000	3.9269	28	3.4000
64	2.7117	5.2500	3.9269	29	3.4000
65	2.7117	5.5000	3.9269	30	3.4000
71	2.7117	4.7000	3.9269	31	3.4000
72	2.7117	4.2500	3.9269	32	3.4000
74	2.7117	2.2500	3.9269	33	3.4000
75	2.7117	2.4000	3.9269	34	3.4000
76	2.7117	2.5000	3.9269	35	3.4000
79	2.7117	4.5500	3.9269	36	3.4000
81	2.7117	4.3000	3.9269	37	3.4000
82	2.7117	4.0000	3.9269	38	3.4000
87	2.7117	4.1500	3.9269	39	3.4000
88	2.7117	4.7000	3.9269	40	3.4000
93	2.7117	4.1000	3.9269	41	3.4000
105	2.7117	2.7000	3.9269	42	3.4000
106	2.7117	2.6500	3.9269	43	3.4000
107	2.7117	2.6000	3.9269	44	3.4000
112	2.7117	4.4000	3.9269	45	3.4000
113	2.7117	5.4500	3.9269	46	3.4000
118	2.7117	4.0000	3.9269	47	3.4000
119	2.7117	4.0500	3.9269	48	3.4000
120	2.7117	4.9500	3.9269	49	3.4000
121	2.7117	5.0500	3.9269	50	3.4000
122	2.7117	5.6000	3.9269	51	3.4000
123	2.7117	5.3500	3.9269	52	3.4000
124	2.7117	4.0500	3.9269	53	3.4000
128	2.7117	4.0500	3.9269	54	3.4000
129	2.7117	5.2000	3.9269	55	3.4000
130	2.7117	4.8000	3.9269	56	3.4000
131	2.7117	4.9000	3.9269	57	3.4000
132	2.7117	4.7500	3.9269	58	3.4000
133	2.7117	4.0500	3.9269	59	3.4000
134	2.7117	4.3000	3.9269	60	3.4000
135	2.7117	4.5500	3.9269	61	3.4000

STATION SUMMARY

STATION NO. 3
 NO. OUTSIDE LIMITS 61
 TOTAL NO. OF OBS. 135

RESULTS FOR STATION NO.

SAMPLE NO.	LOWER LIMIT	OBSERVED VALUE	UPPER LIMIT	NO. OUTSIDE LIMITS	PREDICTED VALUE
7	2.6932	2.4500	3.9312	1	3.4000
9	2.6932	2.3000	3.9312	2	3.4000
15	2.6932	4.1000	3.9312	3	3.4000
18	2.6932	2.6000	3.9312	4	3.4000
20	2.6932	2.6000	3.9312	5	3.4000
22	2.6932	4.1000	3.9312	6	3.4000
23	2.6932	4.9500	3.9312	7	3.4000
26	2.6932	2.3500	3.9312	8	3.4000
27	2.6932	2.1500	3.9312	9	3.4000
28	2.6932	2.4500	3.9312	10	3.4000
29	2.6932	2.2000	3.9312	11	3.4000
32	2.6932	2.6500	3.9312	12	3.4000
34	2.6932	2.4500	3.9312	13	3.4000
35	2.6932	2.3500	3.9312	14	3.4000
36	2.6932	1.6500	3.9312	15	3.4000
37	2.6932	1.2000	3.9312	16	3.4000
39	2.6932	2.5500	3.9312	17	3.4000
48	2.6932	2.6500	3.9312	18	3.4000
49	2.6932	2.3500	3.9312	19	3.4000
50	2.6932	2.0500	3.9312	20	3.4000
51	2.6932	2.6500	3.9312	21	3.4000
53	2.6932	2.5000	3.9312	22	3.4000
57	2.6932	4.0500	3.9312	23	3.4000
58	2.6932	4.1000	3.9312	24	3.4000
59	2.6932	4.0500	3.9312	25	3.4000
60	2.6932	4.0500	3.9312	26	3.4000
61	2.6932	4.5500	3.9312	27	3.4000
62	2.6932	4.6000	3.9312	28	3.4000
63	2.6932	4.8500	3.9312	29	3.4000
64	2.6932	5.0500	3.9312	30	3.4000
65	2.6932	5.2000	3.9312	31	3.4000
66	2.6932	4.0500	3.9312	32	3.4000
70	2.6932	4.1500	3.9312	33	3.4000
71	2.6932	4.3500	3.9312	34	3.4000
72	2.6932	4.2500	3.9312	35	3.4000
74	2.6932	2.3500	3.9312	36	3.4000
75	2.6932	1.6500	3.9312	37	3.4000
76	2.6932	2.4000	3.9312	38	3.4000
79	2.6932	4.0500	3.9312	39	3.4000
86	2.6932	3.9500	3.9312	40	3.4000
87	2.6932	4.6000	3.9312	41	3.4000
88	2.6932	4.7000	3.9312	42	3.4000
106	2.6932	2.5000	3.9312	43	3.4000
107	2.6932	2.5500	3.9312	44	3.4000
112	2.6932	4.9500	3.9312	45	3.4000
113	2.6932	5.3000	3.9312	46	3.4000
114	2.6932	4.4000	3.9312	47	3.4000
115	2.6932	4.3000	3.9312	48	3.4000
116	2.6932	4.3500	3.9312	49	3.4000
119	2.6932	5.1500	3.9312	50	3.4000
120	2.6932	4.8000	3.9312	51	3.4000
121	2.6932	5.2000	3.9312	52	3.4000
122	2.6932	4.8000	3.9312	53	3.4000
123	2.6932	5.2000	3.9312	54	3.4000
124	2.6932	4.2000	3.9312	55	3.4000
125	2.6932	4.1500	3.9312	56	3.4000
126	2.6932	4.5000	3.9312	57	3.4000
127	2.6932	4.7000	3.9312	58	3.4000
128	2.6932	4.8500	3.9312	59	3.4000
129	2.6932	5.1000	3.9312	60	3.4000
130	2.6932	4.7500	3.9312	61	3.4000
131	2.6932	4.8000	3.9312	62	3.4000
132	2.6932	5.3000	3.9312	63	3.4000
134	2.6932	4.3500	3.9312	64	3.4000
135	2.6932	4.8000	3.9312	65	3.4000

STATION SUMMARY

STATION NO. 4
 NO. OUTSIDE LIMITS 65
 TOTAL NO. OF OBS. 135

RESULTS FOR STATION NO. 5

SAMPLE NO.	LOWER LIMIT	OBSERVED VALUE	UPPER LIMIT	NO. OUTSIDE LIMITS	PREDICTED VALUE
1	3.2324	2.1500	4.5380	1	4.0000
2	3.2324	1.9000	4.5380	2	4.0000
3	3.2324	2.5000	4.5380	3	4.0000
4	3.2324	2.6000	4.5380	4	4.0000
25	3.2324	5.0500	4.5380	5	4.0000
27	3.2324	3.0000	4.5380	6	4.0000
28	3.2324	2.5000	4.5380	7	4.0000
29	3.2324	2.7000	4.5380	8	4.0000
30	3.2324	2.8000	4.5380	9	4.0000
31	3.2324	3.0500	4.5380	10	4.0000
32	3.2324	3.0500	4.5380	11	4.0000
34	3.2324	2.8500	4.5380	12	4.0000
35	3.2324	2.8000	4.5380	13	4.0000
36	3.2324	3.2000	4.5380	14	4.0000
37	3.2324	2.7000	4.5380	15	4.0000
39	3.2324	3.1000	4.5380	16	4.0000
40	3.2324	3.2000	4.5380	17	4.0000
41	3.2324	2.9500	4.5380	18	4.0000
42	3.2324	2.8000	4.5380	19	4.0000
44	3.2324	3.1500	4.5380	20	4.0000
52	3.2324	2.8500	4.5380	21	4.0000
54	3.2324	3.0500	4.5380	22	4.0000
55	3.2324	3.2000	4.5380	23	4.0000
61	3.2324	4.8000	4.5380	24	4.0000
62	3.2324	5.1000	4.5380	25	4.0000
63	3.2324	5.1500	4.5380	26	4.0000
64	3.2324	5.2000	4.5380	27	4.0000
65	3.2324	5.3000	4.5380	28	4.0000
66	3.2324	4.9000	4.5380	29	4.0000
67	3.2324	4.8000	4.5380	30	4.0000
68	3.2324	5.1000	4.5380	31	4.0000
69	3.2324	5.7000	4.5380	32	4.0000
70	3.2324	5.9000	4.5380	33	4.0000
71	3.2324	5.1500	4.5380	34	4.0000
77	3.2324	3.1000	4.5380	35	4.0000
78	3.2324	3.2000	4.5380	36	4.0000
84	3.2324	4.8000	4.5380	37	4.0000
85	3.2324	4.6000	4.5380	38	4.0000
86	3.2324	5.1000	4.5380	39	4.0000
87	3.2324	4.5500	4.5380	40	4.0000
88	3.2324	5.6000	4.5380	41	4.0000
92	3.2324	4.7500	4.5380	42	4.0000
93	3.2324	4.9500	4.5380	43	4.0000
94	3.2324	5.2500	4.5380	44	4.0000
95	3.2324	5.3500	4.5380	45	4.0000
106	3.2324	3.2000	4.5380	46	4.0000
107	3.2324	3.0500	4.5380	47	4.0000
116	3.2324	4.8000	4.5380	48	4.0000
117	3.2324	5.1500	4.5380	49	4.0000
118	3.2324	5.4500	4.5380	50	4.0000
119	3.2324	5.3000	4.5380	51	4.0000
120	3.2324	5.3000	4.5380	52	4.0000
121	3.2324	4.9500	4.5380	53	4.0000
124	3.2324	4.9500	4.5380	54	4.0000
125	3.2324	5.2500	4.5380	55	4.0000
126	3.2324	5.7500	4.5380	56	4.0000
127	3.2324	6.0500	4.5380	57	4.0000
128	3.2324	6.4000	4.5380	58	4.0000
129	3.2324	5.9000	4.5380	59	4.0000
130	3.2324	5.3000	4.5380	60	4.0000
131	3.2324	4.7000	4.5380	61	4.0000
132	3.2324	5.1000	4.5380	62	4.0000
133	3.2324	5.8500	4.5380	63	4.0000
134	3.2324	6.5000	4.5380	64	4.0000
135	3.2324	6.5000	4.5380	65	4.0000

STATION SUMMARY

STATION NO. 5
 NO. OUTSIDE LIMITS 65
 TOTAL NO. OF OBS. 135

RESULTS FOR STATION NO. 6

SAMPLE NO.	LOWER LIMIT	OBSERVED VALUE	UPPER LIMIT	NO. OUTSIDE LIMITS	PREDICTED VALUE
1	3.2442	1.9000	4.5374	1	4.0000
2	3.2442	2.0000	4.5374	2	4.0000
3	3.2442	2.4000	4.5374	3	4.0000
4	3.2442	2.8500	4.5374	4	4.0000
14	3.2442	4.6500	4.5374	5	4.0000
22	3.2442	4.5500	4.5374	6	4.0000
25	3.2442	5.1500	4.5374	7	4.0000
27	3.2442	2.5500	4.5374	8	4.0000
28	3.2442	2.7500	4.5374	9	4.0000
29	3.2442	2.7500	4.5374	10	4.0000
30	3.2442	3.0500	4.5374	11	4.0000
31	3.2442	3.1000	4.5374	12	4.0000
32	3.2442	3.2000	4.5374	13	4.0000
34	3.2442	3.0000	4.5374	14	4.0000
35	3.2442	3.1500	4.5374	15	4.0000
36	3.2442	2.8500	4.5374	16	4.0000
37	3.2442	3.0000	4.5374	17	4.0000
40	3.2442	3.1500	4.5374	18	4.0000
41	3.2442	3.1000	4.5374	19	4.0000
42	3.2442	2.9500	4.5374	20	4.0000
43	3.2442	3.1000	4.5374	21	4.0000
51	3.2442	3.2000	4.5374	22	4.0000
52	3.2442	2.5500	4.5374	23	4.0000
57	3.2442	3.1500	4.5374	24	4.0000
61	3.2442	4.6500	4.5374	25	4.0000
62	3.2442	5.1000	4.5374	26	4.0000
63	3.2442	5.2000	4.5374	27	4.0000
64	3.2442	5.3000	4.5374	28	4.0000
65	3.2442	5.1000	4.5374	29	4.0000
66	3.2442	4.9500	4.5374	30	4.0000
67	3.2442	5.3500	4.5374	31	4.0000
68	3.2442	5.4000	4.5374	32	4.0000
69	3.2442	4.9000	4.5374	33	4.0000
70	3.2442	5.8500	4.5374	34	4.0000
71	3.2442	6.2500	4.5374	35	4.0000
72	3.2442	4.5500	4.5374	36	4.0000
84	3.2442	4.7500	4.5374	37	4.0000
86	3.2442	5.1000	4.5374	38	4.0000
87	3.2442	5.1000	4.5374	39	4.0000
88	3.2442	5.2500	4.5374	40	4.0000
89	3.2442	4.7500	4.5374	41	4.0000
92	3.2442	4.9000	4.5374	42	4.0000
93	3.2442	4.9500	4.5374	43	4.0000
94	3.2442	5.2500	4.5374	44	4.0000
95	3.2442	4.8500	4.5374	45	4.0000
110	3.2442	3.2000	4.5374	46	4.0000
116	3.2442	5.0000	4.5374	47	4.0000
117	3.2442	4.9500	4.5374	48	4.0000
118	3.2442	4.9000	4.5374	49	4.0000
119	3.2442	4.8500	4.5374	50	4.0000
120	3.2442	4.7500	4.5374	51	4.0000
121	3.2442	4.6500	4.5374	52	4.0000
122	3.2442	4.7000	4.5374	53	4.0000
123	3.2442	4.7000	4.5374	54	4.0000
124	3.2442	5.5000	4.5374	55	4.0000
125	3.2442	5.5000	4.5374	56	4.0000
126	3.2442	5.9000	4.5374	57	4.0000
127	3.2442	6.1000	4.5374	58	4.0000
128	3.2442	6.4500	4.5374	59	4.0000
129	3.2442	5.6500	4.5374	60	4.0000
130	3.2442	5.7000	4.5374	61	4.0000
131	3.2442	5.1500	4.5374	62	4.0000
132	3.2442	5.0000	4.5374	63	4.0000
133	3.2442	6.1000	4.5374	64	4.0000
134	3.2442	6.6500	4.5374	65	4.0000
135	3.2442	6.5500	4.5374	66	4.0000

STATION SUMMARY

STATION NO. 6
 NO. OUTSIDE LIMITS 66
 TOTAL NO. OF OBS. 135

RESULTS FOR STATION NO. 7

SAMPLE NO.	LOWER LIMIT	OBSERVED VALUE	UPPER LIMIT	NO. OUTSIDE LIMITS	PREDICTED VALUE
1	3.9566	2.9000	5.1105	1	4.6000
2	3.9566	3.4000	5.1105	2	4.6000
3	3.9566	2.3500	5.1105	3	4.6000
4	3.9566	2.1500	5.1105	4	4.6000
5	3.9566	2.9000	5.1105	5	4.6000
6	3.9566	3.1000	5.1105	6	4.6000
7	3.9566	2.5500	5.1105	7	4.6000
8	3.9566	3.2000	5.1105	8	4.6000
9	3.9566	3.1500	5.1105	9	4.6000
10	3.9566	3.7000	5.1105	10	4.6000
11	3.9566	3.7500	5.1105	11	4.6000
21	3.9566	5.4000	5.1105	12	4.6000
22	3.9566	5.2000	5.1105	13	4.6000
29	3.9566	5.6500	5.1105	14	4.6000
30	3.9566	5.7500	5.1105	15	4.6000
31	3.9566	5.3000	5.1105	16	4.6000
34	3.9566	3.8000	5.1105	17	4.6000
35	3.9566	3.9500	5.1105	18	4.6000
36	3.9566	3.3500	5.1105	19	4.6000
37	3.9566	2.9000	5.1105	20	4.6000
39	3.9566	3.8000	5.1105	21	4.6000
40	3.9566	3.8000	5.1105	22	4.6000
42	3.9566	3.5500	5.1105	23	4.6000
50	3.9566	3.5500	5.1105	24	4.6000
51	3.9566	3.4500	5.1105	25	4.6000
52	3.9566	3.3000	5.1105	26	4.6000
53	3.9566	3.8000	5.1105	27	4.6000
54	3.9566	3.8500	5.1105	28	4.6000
55	3.9566	3.9500	5.1105	29	4.6000
72	3.9566	5.2000	5.1105	30	4.6000
73	3.9566	5.3000	5.1105	31	4.6000
74	3.9566	5.2000	5.1105	32	4.6000
76	3.9566	5.8500	5.1105	33	4.6000
77	3.9566	6.0000	5.1105	34	4.6000
78	3.9566	5.3500	5.1105	35	4.6000
79	3.9566	5.5500	5.1105	36	4.6000
80	3.9566	5.5000	5.1105	37	4.6000
81	3.9566	5.2000	5.1105	38	4.6000
82	3.9566	5.2500	5.1105	39	4.6000
83	3.9566	5.3000	5.1105	40	4.6000
84	3.9566	5.4000	5.1105	41	4.6000
85	3.9566	5.2500	5.1105	42	4.6000
88	3.9566	5.7000	5.1105	43	4.6000
93	3.9566	5.1500	5.1105	44	4.6000
94	3.9566	5.2000	5.1105	45	4.6000
95	3.9566	5.3000	5.1105	46	4.6000
96	3.9566	5.3500	5.1105	47	4.6000
97	3.9566	5.5000	5.1105	48	4.6000
98	3.9566	5.3000	5.1105	49	4.6000
99	3.9566	5.2000	5.1105	50	4.6000
100	3.9566	5.4500	5.1105	51	4.6000
101	3.9566	5.2500	5.1105	52	4.6000
102	3.9566	5.5000	5.1105	53	4.6000
103	3.9566	5.7500	5.1105	54	4.6000
104	3.9566	5.3500	5.1105	55	4.6000
105	3.9566	5.3000	5.1105	56	4.6000
108	3.9566	5.1500	5.1105	57	4.6000
110	3.9566	5.2000	5.1105	58	4.6000
131	3.9566	5.2000	5.1105	59	4.6000
132	3.9566	5.1500	5.1105	60	4.6000
133	3.9566	5.6500	5.1105	61	4.6000
134	3.9566	5.4000	5.1105	62	4.6000
135	3.9566	5.4000	5.1105	63	4.6000

STATION SUMMARY

STATION NO. 7
 NO. OUTSIDE LIMITS 63
 TOTAL NO. OF OBS. 135

RESULTS FOR STATION NO. 8

SAMPLE NO.	LOWER LIMIT	OBSERVED VALUE	UPPER LIMIT	NO. OUTSIDE LIMITS	PREDICTED VALUE
1	4.2380	3.5500	5.3068	1	4.8300
2	4.2380	3.9500	5.3068	2	4.8300
3	4.2380	3.6000	5.3068	3	4.8300
4	4.2380	3.4000	5.3068	4	4.8300
8	4.2380	4.2000	5.3068	5	4.8300
9	4.2380	3.5000	5.3068	6	4.8300
10	4.2380	3.3500	5.3068	7	4.8300
11	4.2380	3.2500	5.3068	8	4.8300
12	4.2380	2.9500	5.3068	9	4.8300
13	4.2380	3.2500	5.3068	10	4.8300
14	4.2380	3.4500	5.3068	11	4.8300
15	4.2380	3.7000	5.3068	12	4.8300
16	4.2380	3.5500	5.3068	13	4.8300
17	4.2380	3.8500	5.3068	14	4.8300
18	4.2380	3.5500	5.3068	15	4.8300
19	4.2380	3.7500	5.3068	16	4.8300
20	4.2380	4.0500	5.3068	17	4.8300
30	4.2380	5.4000	5.3068	18	4.8300
35	4.2380	5.4500	5.3068	19	4.8300
36	4.2380	5.4000	5.3068	20	4.8300
37	4.2380	5.5500	5.3068	21	4.8300
38	4.2380	5.5500	5.3068	22	4.8300
39	4.2380	5.6500	5.3068	23	4.8300
40	4.2380	5.6000	5.3068	24	4.8300
49	4.2380	4.2000	5.3068	25	4.8300
50	4.2380	3.8000	5.3068	26	4.8300
51	4.2380	3.7000	5.3068	27	4.8300
52	4.2380	3.8000	5.3068	28	4.8300
53	4.2380	4.0000	5.3068	29	4.8300
54	4.2380	4.0000	5.3068	30	4.8300
55	4.2380	4.0500	5.3068	31	4.8300
56	4.2380	4.0500	5.3068	32	4.8300
66	4.2380	4.0500	5.3068	33	4.8300
74	4.2380	4.2000	5.3068	34	4.8300
75	4.2380	3.8500	5.3068	35	4.8300
79	4.2380	5.4500	5.3068	36	4.8300
80	4.2380	5.6000	5.3068	37	4.8300
81	4.2380	5.5000	5.3068	38	4.8300
82	4.2380	5.3500	5.3068	39	4.8300
83	4.2380	5.7500	5.3068	40	4.8300
84	4.2380	5.7000	5.3068	41	4.8300
85	4.2380	5.9500	5.3068	42	4.8300
86	4.2380	6.0500	5.3068	43	4.8300
87	4.2380	6.2500	5.3068	44	4.8300
88	4.2380	6.3500	5.3068	45	4.8300
89	4.2380	5.8000	5.3068	46	4.8300
90	4.2380	5.5500	5.3068	47	4.8300
91	4.2380	5.9000	5.3068	48	4.8300
92	4.2380	5.8500	5.3068	49	4.8300
93	4.2380	5.6500	5.3068	50	4.8300
94	4.2380	5.5000	5.3068	51	4.8300
106	4.2380	5.4500	5.3068	52	4.8300
115	4.2380	5.3500	5.3068	53	4.8300
116	4.2380	5.4000	5.3068	54	4.8300
117	4.2380	5.6000	5.3068	55	4.8300
118	4.2380	5.5500	5.3068	56	4.8300
119	4.2380	5.5000	5.3068	57	4.8300
120	4.2380	5.4000	5.3068	58	4.8300
121	4.2380	5.4500	5.3068	59	4.8300

STATION SUMMARY

STATION NO.	8
NO. OUTSIDE LIMITS	59
TOTAL NO. OF OBS.	135

READ THE NUMBER OF LEVELS FOR EACH INDEPENDENT VARIABLE

```

      READ(5,15) (NLEV(I), I = 1, NVARM1)
15  FORMAT(5I5)

```

```

      NLEV1 = NLEV(1)
      NLEV2 = NLEV(2)
      NLEV3 = NLEV(3)
      NLEV4 = NLEV(4)
      NLEV5 = NLEV(5)

```

```

      READ IN THE RANGE NUMBERS FOR EACH INDEPENDENT VARIABLE

```

```

      DO 20 I = 1, NVARM1
      NLEVMI(I) = NLEV(I) - 1
      M1 = NLEVMI(I)
20  READ (5,25) (RANGE(I,J), J=1, M1)
25  FORMAT(8F10.0)

```

```

      READ THE FORMAT CARD

```

```

      DO 30 I = 1, NFMT
      K = I + 20
      J = K - 19
30  READ(5,35) (FMT(I1), I1=J, K)
35  FORMAT(20A4)

```

```

      DO LOOP TO READ IN DATA AND SORT ACCORDING TO THE SPECIFIED RANGE

```

```

      DO 52 I = 1, NDATA

```

```

      READ THE DATA

```

```

      READ(5,FMT) (DATA(I1), I1=1, NVAR)
      DO 40 J=1, NVAR

```

```

      REARRANGE DATA TO PUT DEPENDENT VARIABLE (I.E. THE VARIABLE THAT
      DELTA IS COMPUTED FROM) FIRST (I.E. Y(I)= DEPENDENT VARIABLE

```



```

C      40 Y(J) = DATA(ID(J))
C
C      LOOP TO SORT INDEPENDENT VARIABLE OR FACTORS INTO LEVELS OR RANGE
C
      DO 50 J=2,NVAR
      JM1 = J - 1
      L(J) = 1
      IF (NLEV(JM1).EQ.1) GO TO 50
      M2 = NLEVJM1(JM1)
      DO 45 K=1,M2
      IF (Y(J) .GT. RANGE(JM1,K)) GO TO 45
      L(J) = K
      GO TO 50
45 CONTINUE
      L(J) = NLEV(JM1)
50 CONTINUE
      ICOUNT(1,L(2),L(3),L(4),L(5),L(6)) = ICOUNT(1,L(2),L(3),L(4),L(5),
      1L(6)) + 1
C
C      DO LOOP TO COMPUTE THE TOTALS FOR EACH VARIABLE SO THAT THE LEVEL
C      AVERAGES CAN BE COMPUTED
C
      DO 51 M=2,NVAR
      MM1 = M - 1
      JI= L(M)
      TOT(MM1,JI)= TOT(MM1,JI)+ Y(M)
51 ICNT(MM1,JI)= ICNT(MM1,JI)+ 1
C
C      CHECK TO SEE IF DELTAS ARE TO BE COMPUTED ON THIS RUN
C
      IF (XYZ .EQ. 0.0) GO TO 52
C
C      COMPUTE SUM OF DEPENDENT VARIABLES FOR EACH CELL
C

```

```

C
C
C
      S (1,L(2),L(3),L(4),L(5),L(6)) = S (1,L(2),L(3),L(4),L(5),L(6)) +
1 Y(1)

      COMPUTE SUM OF SQUARED DEPENDENT VARIABLES FOR EACH CELL

      SQ(1,L(2),L(3),L(4),L(5),L(6)) = SQ(1,L(2),L(3),L(4),L(5),L(6)) +
1 Y(1)**2
52 CONTINUE
DO 55 I=1,NVARM1
  K = NLEV(I)
DO 55 J=1,K
  IF (ICNT(I,J) .NE. 0) GO TO 54
  WRITE(6,53) I,J
53 FORMAT(//,10X,'NO OBSERVATIONS FOR FACTOR',I2,', LEVEL',I2,////)
  GO TO 55
54 R = ICNT(I,J)

      COMPUTE LEVEL AVERAGES

      A(I,J) = TOT(I,J) / R
55 CONTINUE
  IF(XYZ .EQ. 0.0) GO TO 75
  WRITE(6,999)
999 FORMAT('1')
DO 70 I6 = 1,NLEV5
DO 70 I5 = 1,NLEV4
DO 70 I4 = 1,NLEV3
DO 70 I3 = 1,NLEV2
DO 70 I2 = 1,NLEV1

      CHECK TO SEE IF THE NUMBER OF OBSERVATIONS IN A CELL EQUALS OR
      EXCEEDS THE SPECIFIED MINIMUM NUMBER

      IF (ICOUNT(1,I2,I3,I4,I5,I6) .LT. NMIN) GO TO 60
      RN = ICOUNT(1,I2,I3,I4,I5,I6)

```

```

C
C
C      COMPUTE THE SAMPLE VARIANCE FOR EACH CELL
C
C      SSQ = (SQ(I2,I3,I4,I5,I6) - ((S(I2,I3,I4,I5,I6)**2)/RN))/(RN -
C      1)
C
C      COMPUTE THE DELTA FOR THIS CELL
C
C      DELTA(I2,I3,I4,I5,I6) = (RN*SSQ) / S(I2,I3,I4,I5,I6)
C      JN = RN
C      B(1) = A(I2,I3)
C      B(2) = A(I2,I4)
C      B(3) = A(I2,I5)
C      B(4) = A(I2,I6)
C      B(5) = A(I3,I4)
C      B(6) = A(I3,I5)
C      B(7) = A(I3,I6)
C      B(8) = A(I4,I5)
C      B(9) = A(I4,I6)
C      B(10) = A(I5,I6)
C      WRITE(6,59) JN,DELTA(I2,I3,I4,I5,I6), (B(I),I=1,NVARM1)
C      WRITE(7,59) JN,DELTA(I2,I3,I4,I5,I6), (B(I),I=1,NVARM1)
C      59 FORMAT(I5,F10.5,5X,5F12.4)
C
C      IF YOU DESIRE TO WRITE AND PUNCH THE LEVEL NUMBERS INSTEAD OF THE
C      LEVEL AVERAGES, REPLACE THE CARDS WITH AVE IN COLUMNS 75-77
C      WITH THE FOLLOWING 8 CARDS DELETING THE C IN THE FIRST COLU
C      MNS
C      IB(1) = I2
C      IB(2) = I3
C      IB(3) = I4
C      IB(4) = I5
C      IB(5) = I6
C      WRITE(6,59) JN,DELTA(I2,I3,I4,I5,I6), (IB(I),I=1,NVARM1)
C      WRITE(7,59) JN,DELTA(I2,I3,I4,I5,I6), (IB(I),I=1,NVARM1)
C      59 FORMAT(I5,F10.5,5X,5I12)
C
C      GO TO 70
C

```


LEVELS SHOWING THE OCCURRENCE FREQUENCY OF THE SAMPLE SIZES
IN THE CELLS FOR FACTOR 1. THIS IS DONE SEPERATELY FOR EAC
OF ITS NLEV(1) LEVELS.

```

IJ = 1
WRITE(6,87) IJ
87 FORMAT(//////,2X,'FACTOR NUMBER',I2,/)
WRITE(6,91)
91 FORMAT(34X,'GREATER THAN',5X,'LESS THAN OR EQUAL TO',10X,'AVERAGE
WITHIN LEVEL',5X,'NO. OBS. PER LEVEL')
WRITE(6,92) RANGE(IJ,1),A(IJ,1),ICNT(IJ,1)
92 FORMAT(20X,'LEVEL 1',25X,F12.3,19X,F12.4,16X,I6)
M1 = NLEVMI(IJ)
IF (NLEV(IJ) .EQ. 2) GO TO 96
DO 93 I=2,M1
IM1 = I - 1
93 WRITE(6,94) I,RANGE(IJ,IM1),RANGE(IJ,I),A(IJ,I),ICNT(IJ,I)
94 FORMAT(20X,'LEVEL ',I2,5X,F12.3,8X,F12.3,19X,F12.4,16X,I6)
96 NL = NLEV(IJ)
WRITE(6,97) NLEV(IJ),RANGE(IJ,M1),A(IJ,NL),ICNT(IJ,NL)
97 FORMAT(20X,'LEVEL ',I2,5X,F12.3,39X,F12.4,16X,I6,////)
DO 95 I = 1,NLEV1
DO 88 II= 1,21
88 IHIST(II)= 0
DO 89 I6 = 1,NLEV5
DO 89 I5 = 1,NLEV4
DO 89 I4 = 1,NLEV3
DO 89 I3 = 1,NLEV2
J = ICOUNT(1, I,I3,I4,I5,I6)
IF (J .GT. 20) J = 20
JP1 = J + 1
89 IHIST(JP1) = IHIST(JP1) + 1
WRITE(6,90) I,(IHIST(K),K=1,21),(KK,KK=1,20)
90 FORMAT(8X,'LEVEL NUMBER',I2,5X,'FREQUENCY',5X,21(I3,1X),//,17X,'NU
MBER OBSERVATIONS',7X,'0',20(2X,I2),////)

```

```

95 CONTINUE
IF (NVAR .EQ. 2) GO TO 160

C
C
C   COMPUTE THE HISTOGRAM FOR FACTOR 2

IJ = 2
WRITE(6,87) IJ
WRITE(6,91)
WRITE(6,92) RANGE(IJ,1),A(IJ,1),ICNT(IJ,1)
M1 = NLEVMI(IJ)
IF (NLEV(IJ) .EQ. 2) GO TO 99
DO 98 I=2,M1
IM1 = I - 1
98 WRITE(6,94) I,RANGE(IJ,IM1),RANGE(IJ,I),A(IJ,I),ICNT(IJ,I)
99 NL = NLEV(IJ)
WRITE(6,97) NLEV(IJ),RANGE(IJ,M1),A(IJ,NL),ICNT(IJ,NL)
DO 110 I = 1,NLEV2
DO 100 II= 1,21
100 IHIST(II)= 0
DO 105 I6 = 1,NLEV5
DO 105 I5 = 1,NLEV4
DO 105 I4 = 1,NLEV3
DO 105 I2 = 1,NLEV1
J = ICOUNT(I,I2, I,I4,I5,I6)
IF (J .GT. 20) J = 20
JP1 = J + 1
105 IHIST(JP1) = IHIST(JP1) + 1
WRITE(6,90) I,(IHIST(K),K=1,21),(KK,KK=1,20)
110 CONTINUE
IF (NVAR .EQ. 3) GO TO 160

C
C
C   COMPUTE THE HISTOGRAM FOR FACTOR 3

IJ = 3
WRITE(6,87) IJ

```



```

WRITE(6,91)
WRITE(6,92) RANGE(IJ,1),A(IJ,1),ICNT(IJ,1)
M1 = NLEVMI(IJ)
IF (NLEV(IJ) .EQ. 2) GO TO 112
DO 111 I=2,M1
IM1 = I - 1
111 WRITE(6,94) I,RANGE(IJ,IM1),RANGE(IJ,I),A(IJ,I),ICNT(IJ,I)
112 NL = NLEV(IJ)
WRITE(6,97) NLEV(IJ),RANGE(IJ,M1),A(IJ,NL),ICNT(IJ,NL)
DO 125 I = 1,NLEV3
DO 115 II= 1,21
115 IHIST(II)= 0
DO 120 I6 = 1,NLEV5
DO 120 I5 = 1,NLEV4
DO 120 I3 = 1,NLEV2
DO 120 I2 = 1,NLEV1
J = ICOUNT(I,I2,I3,I,I5,I6)
IF (J .GT. 20) J = 20
JP1 = J + 1
120 IHIST(JP1) = IHIST(JP1) + 1
WRITE(6,90) I,(IHIST(K),K=1,21),(KK,KK=1,20)
125 CONTINUE
IF (NVAR .EQ. 4) GO TO 160

C
C
C
COMPUTE THE HISTOGRAM FOR FACTOR 4

IJ = 4
WRITE(6,87) IJ
WRITE(6,91)
WRITE(6,92) RANGE(IJ,1),A(IJ,1),ICNT(IJ,1)
M1 = NLEVMI(IJ)
IF (NLEV(IJ) .EQ. 2) GO TO 127
DO 126 I=2,M1
IM1 = I - 1
126 WRITE(6,94) I,RANGE(IJ,IM1),RANGE(IJ,I),A(IJ,I),ICNT(IJ,I)

```

```

127 NL = NLEV(IJ)
   WRITE(6,97) NLEV(IJ), RANGE(IJ,M1), A(IJ,NL), ICNT(IJ,NL)
   DO 140 I = 1, NLEV4
   DO 130 II = 1, 21
130 IHIST(II) = 0
   DO 135 I6 = 1, NLEV5
   DO 135 I4 = 1, NLEV3
   DO 135 I3 = 1, NLEV2
   DO 135 I2 = 1, NLEV1
   J = ICOUNT(I,I2,I3,I4, I,I6)
   IF (J .GT. 20) J = 20
   JP1 = J + 1
135 IHIST(JP1) = IHIST(JP1) + 1
   WRITE(6,90) I, (IHIST(K), K=1,21), (KK, KK=1,20)
140 CONTINUE
   IF (NVAR .EQ. 5) GO TO 160

      C
      C
      C
      COMPUTE THE HISTOGRAM FOR FACTOR 5

      IJ = 5
      WRITE(6,87) IJ
      WRITE(6,91)
      WRITE(6,92) RANGE(IJ,1), A(IJ,1), ICNT(IJ,1)
      M1 = NLEVMI(IJ)
      IF (NLEV(IJ) .EQ. 2) GO TO 142
      DO 141 I=2,M1
      IM1 = I - 1
141 WRITE(6,94) I, RANGE(IJ, IM1), RANGE(IJ, I), A(IJ, I), ICNT(IJ, I)
142 NL = NLEV(IJ)
      WRITE(6,97) NLEV(IJ), RANGE(IJ,M1), A(IJ,NL), ICNT(IJ,NL)
      DO 155 I = 1, NLEV5
      DO 145 II = 1, 21
145 IHIST(II) = 0
      DO 150 I5 = 1, NLEV4
      DO 150 I4 = 1, NLEV3

```

```

00 150 I3 = 1, NLEV2
00 150 I2 = 1, NLEV1
J = ICOUNT(1, I2, I3, I4, I5, I)
IF (J .GT. 20) J = 20
JPI = J + 1
150 IHIST(JPI) = IHIST(JPI) + 1
WRITE(6, 90) 1, (IHIST(K), K=1, 21), (KK, KK=1, 20)
155 CONTINUE
160 CONTINUE
WRITE(6, 999)
998 STOP
END

```


20	0.05461	2.0000 263889.4375	23.5055	1.6027
ICOUNT (1, 2, 1, 1, 1, 1) = 1				
ICOUNT (1, 3, 1, 1, 1, 1) = 0				
10	0.19408	5.0000 263889.4375	23.5055	1.6027
9	0.17904	6.0000 263889.4375	23.5055	1.6027
26	0.05967	7.0000 263889.4375	23.5055	1.6027
28	0.05371	8.0000 263889.4375	23.5055	1.6027
29	0.07712	2.0000 868852.3750	23.5055	1.6027
ICOUNT (1, 2, 2, 1, 1, 1) = 0				
ICOUNT (1, 3, 2, 1, 1, 1) = 0				
16	0.28879	5.0000 868852.3750	23.5055	1.6027
14	0.19410	6.0000 868852.3750	23.5055	1.6027
17	0.04719	7.0000 868852.3750	23.5055	1.6027
23	0.05419	8.0000 868852.3750	23.5055	1.6027
13	0.06619	2.0000 1464266.0000	23.5055	1.6027
ICOUNT (1, 2, 3, 1, 1, 1) = 0				
ICOUNT (1, 3, 3, 1, 1, 1) = 0				
8	0.13490	5.0000 1464266.0000	23.5055	1.6027
9	0.21710	6.0000 1464266.0000	23.5055	1.6027
12	0.04046	7.0000 1464266.0000	23.5055	1.6027
12	0.03620	8.0000 1464266.0000	23.5055	1.6027
25	0.05018	2.0000 2063833.0000	23.5055	1.6027
2	0.33800	3.0000 2063833.0000	23.5055	1.6027
ICOUNT (1, 3, 4, 1, 1, 1) = 0				
6	0.16254	5.0000 2063833.0000	23.5055	1.6027
9	0.21324	6.0000 2063833.0000	23.5055	1.6027
27	0.13808	7.0000 2063833.0000	23.5055	1.6027
28	0.07296	8.0000 2063833.0000	23.5055	1.6027
4	0.48095	2.0000 263889.4375	24.6704	1.6027
ICOUNT (1, 2, 1, 2, 1, 1) = 0				
ICOUNT (1, 3, 1, 2, 1, 1) = 0				
ICOUNT (1, 4, 1, 2, 1, 1) = 0				
ICOUNT (1, 5, 1, 2, 1, 1) = 0				
5	0.23566	7.0000 263889.4375	24.6704	1.6027
6	0.04058	8.0000 263889.4375	24.6704	1.6027
2	0.00254	2.0000 868852.3750	24.6704	1.6027
ICOUNT (1, 2, 2, 2, 1, 1) = 0				
ICOUNT (1, 3, 2, 2, 1, 1) = 0				
2	0.00132	5.0000 868852.3750	24.6704	1.6027
4	0.05555	6.0000 868852.3750	24.6704	1.6027
14	0.12647	7.0000 868852.3750	24.6704	1.6027
7	0.03857	8.0000 868852.3750	24.6704	1.6027
14	0.13248	2.0000 1464266.0000	24.6704	1.6027
ICOUNT (1, 2, 3, 2, 1, 1) = 0				
ICOUNT (1, 3, 3, 2, 1, 1) = 0				
6	0.15267	5.0000 1464266.0000	24.6704	1.6027
4	0.18250	6.0000 1464266.0000	24.6704	1.6027
17	0.10067	7.0000 1464266.0000	24.6704	1.6027
19	0.12871	8.0000 1464266.0000	24.6704	1.6027
3	0.06748	2.0000 2063833.0000	24.6704	1.6027
ICOUNT (1, 2, 4, 2, 1, 1) = 0				
ICOUNT (1, 3, 4, 2, 1, 1) = 0				
ICOUNT (1, 4, 4, 2, 1, 1) = 0				
ICOUNT (1, 5, 4, 2, 1, 1) = 0				
ICOUNT (1, 6, 4, 2, 1, 1) = 1				

3	0.16145	0.0000206389.4375	24.6704	1.6027
9	0.00642	2.0000 263889.4375	23.5055	2.6431
21	0.10351	3.0000 263889.4375	23.5055	2.6431
19	0.16302	4.0000 263889.4375	23.5055	2.6431
19	0.29511	5.0000 263889.4375	23.5055	2.6431
20	0.27632	6.0000 263889.4375	23.5055	2.6431
2	0.00154	7.0000 263889.4375	23.5055	2.6431
ICOUNT (1, 7, 1, 1, 2, 1) = 0				
2	0.04706	2.0000 868852.3750	23.5055	2.6431
13	0.19419	3.0000 868852.3750	23.5055	2.6431
10	0.23397	4.0000 868852.3750	23.5055	2.6431
9	0.28369	5.0000 868852.3750	23.5055	2.6431
6	0.32131	6.0000 868852.3750	23.5055	2.6431
ICOUNT (1, 6, 2, 1, 2, 1) = 0				
ICOUNT (1, 7, 2, 1, 2, 1) = 1				
ICOUNT (1, 1, 3, 1, 2, 1) = 0				
9	0.11903	3.0000 1464266.0000	23.5055	2.6431
11	0.19582	4.0000 1464266.0000	23.5055	2.6431
6	0.22522	5.0000 1464266.0000	23.5055	2.6431
8	0.14981	6.0000 1464266.0000	23.5055	2.6431
ICOUNT (1, 6, 3, 1, 2, 1) = 1				
ICOUNT (1, 7, 3, 1, 2, 1) = 0				
2	0.20769	2.0000 2063833.0000	23.5055	2.6431
20	0.17214	3.0000 2063833.0000	23.5055	2.6431
21	0.16163	4.0000 2063833.0000	23.5055	2.6431
22	0.25646	5.0000 2063833.0000	23.5055	2.6431
19	0.24118	6.0000 2063833.0000	23.5055	2.6431
3	0.01409	7.0000 2063833.0000	23.5055	2.6431
ICOUNT (1, 7, 4, 1, 2, 1) = 1				
9	0.27669	2.0000 263889.4375	24.6704	2.6431
3	0.00402	3.0000 263889.4375	24.6704	2.6431
ICOUNT (1, 3, 1, 2, 2, 1) = 0				
9	0.10376	5.0000 263889.4375	24.6704	2.6431
8	0.07355	6.0000 263889.4375	24.6704	2.6431
ICOUNT (1, 6, 1, 2, 2, 1) = 1				
ICOUNT (1, 7, 1, 2, 2, 1) = 1				
6	0.08533	2.0000 868852.3750	24.6704	2.6431
9	0.02147	3.0000 868852.3750	24.6704	2.6431
2	0.03138	4.0000 868852.3750	24.6704	2.6431
4	0.03955	5.0000 868852.3750	24.6704	2.6431
7	0.21038	6.0000 868852.3750	24.6704	2.6431
2	0.17536	7.0000 868852.3750	24.6704	2.6431
2	0.00035	8.0000 868852.3750	24.6704	2.6431
7	0.08436	9.0000 1464266.0000	24.6704	2.6431
14	0.16606	3.0000 1464266.0000	24.6704	2.6431
11	0.20856	4.0000 1464266.0000	24.6704	2.6431
10	0.10015	5.0000 1464266.0000	24.6704	2.6431
10	0.20821	6.0000 1464266.0000	24.6704	2.6431
4	0.34868	7.0000 1464266.0000	24.6704	2.6431
9	0.05970	8.0000 1464266.0000	24.6704	2.6431
4	0.40133	9.0000 2063833.0000	24.6704	2.6431
6	0.05690	3.0000 2063833.0000	24.6704	2.6431
3	0.04815	4.0000 2063833.0000	24.6704	2.6431
9	0.08993	5.0000 2063833.0000	24.6704	2.6431
9	0.10922	6.0000 2063833.0000	24.6704	2.6431
3	0.38208	7.0000 2063833.0000	24.6704	2.6431
2	0.03189	8.0000 2063833.0000	24.6704	2.6431
ICOUNT (1, 1, 1, 1, 3, 1) = 0				
4	0.03180	3.0000 263889.4375	23.5055	3.9642
10	0.02315	4.0000 263889.4375	23.5055	3.9642
ICOUNT (1, 4, 1, 1, 3, 1) = 0				
ICOUNT (1, 5, 1, 1, 3, 1) = 0				
ICOUNT (1, 6, 1, 1, 3, 1) = 0				
ICOUNT (1, 7, 1, 1, 3, 1) = 0				
ICOUNT (1, 1, 2, 1, 3, 1) = 0				
4	0.12949	3.0000 868852.3750	23.5055	3.9642
6	0.07687	4.0000 868852.3750	23.5055	3.9642

SECUNT 0 10 40 20 10 40 10 = 1				
SECUNT 0 10 40 20 10 10 10 = 1				
SECUNT 0 10 40 20 10 10 10 = 0				
SECUNT 0 10 70 20 10 30 10 = 0				
SECUNT 0 10 10 30 10 30 10 = 0				
SECUNT 0 10 20 30 10 30 10 = 1				
SECUNT 0 10 30 30 10 30 10 = 1				
SECUNT 0 10 40 30 10 30 10 = 0				
SECUNT 0 10 50 30 10 30 10 = 0				
SECUNT 0 10 60 30 10 30 10 = 0				
SECUNT 0 10 70 30 10 30 10 = 0				
SECUNT 0 10 10 40 10 30 10 = 0				
4	0010410	30000020438330000	2305055	309042
9	0005871	40000020438330000	2305055	309042
SECUNT 0 10 40 40 10 30 10 = 0				
SECUNT 0 10 50 40 10 30 10 = 0				
SECUNT 0 10 60 40 10 30 10 = 0				
SECUNT 0 10 70 40 10 30 10 = 0				
SECUNT 0 10 10 10 20 30 10 = 0				
5	0007686	30000020438330000	2406704	309042
9	0023206	40000020438330000	2406704	309042
SECUNT 0 10 40 10 20 30 10 = 1				
SECUNT 0 10 50 10 20 30 10 = 0				
SECUNT 0 10 60 10 20 30 10 = 0				
SECUNT 0 10 70 10 20 30 10 = 0				
SECUNT 0 10 10 20 20 30 10 = 0				
7	0004147	30000020438330000	2406704	309042
7	0007800	40000020438330000	2406704	309042
3	0009882	30000020438330000	2406704	309042
2	0009890	40000020438330000	2406704	309042
SECUNT 0 10 40 20 20 30 10 = 0				
SECUNT 0 10 70 20 20 30 10 = 0				
SECUNT 0 10 10 30 20 30 10 = 0				
8	0009707	30000020438330000	2406704	309042
11	0009489	40000020438330000	2406704	309042
4	0003213	30000020438330000	2406704	309042
9	0004666	40000020438330000	2406704	309042
SECUNT 0 10 40 30 20 30 10 = 0				
SECUNT 0 10 70 30 20 30 10 = 0				
SECUNT 0 10 10 40 20 30 10 = 0				
2	0008346	30000020438330000	2406704	309042
9	0004082	40000020438330000	2406704	309042
SECUNT 0 10 40 40 20 30 10 = 1				
SECUNT 0 10 50 40 20 30 10 = 1				
SECUNT 0 10 60 40 20 30 10 = 0				
SECUNT 0 10 70 40 20 30 10 = 0				

AFTER THE DATA HAS BEEN SORTED ACCORDING TO THE PREVIOUSLY GIVEN FACTOR
RANGES, WE HAVE THE FOLLOWING FREQUENCY OF SAMPLE SIZES FOR COMPUTING THE DELTAS.

FREQUENCY	57	11	12	9	8	13	10	5	3	4	4	3	2	1	3	1	2	2	1	4	13
NUMBER OBSERVATIONS	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

LEVEL	GREATER THAN	LESS THAN OR EQUAL TO	AVERAGE WITHIN LEVEL	NO. OBS. PER LEVEL
LEVEL 1		2.000	2.00000	135
LEVEL 2	2.000	3.000	3.00000	135
LEVEL 3	3.000	4.000	4.00000	135
LEVEL 4	4.000	5.000	5.00000	135
LEVEL 5	5.000	6.000	6.00000	135
LEVEL 6	6.000	7.000	7.00000	135
LEVEL 7	7.000		8.00000	135

LEVEL NUMBER 1	FREQUENCY	9	0	3	1	2	2	1	1	0	0	0	0	1	1	0	0	0	3	3		
NUMBER OBSERVATIONS		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

LEVEL NUMBER 2	FREQUENCY	6	2	2	1	2	2	2	1	1	1	0	0	0	0	1	1	0	0	0	2	
NUMBER OBSERVATIONS		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

LEVEL NUMBER 3	FREQUENCY	9	1	1	1	0	3	1	1	0	0	1	3	0	0	0	0	0	1	1	1	
NUMBER OBSERVATIONS		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

LEVEL NUMBER 4	FREQUENCY	6	2	1	1	1	3	4	0	1	0	2	0	0	0	0	1	0	0	1	1	
NUMBER OBSERVATIONS		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

LEVEL NUMBER 5	FREQUENCY	7	1	1	1	2	2	1	1	1	3	1	0	0	0	1	0	0	0	1	1	
NUMBER OBSERVATIONS		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

LEVEL NUMBER 6	FREQUENCY	9	3	2	2	1	1	0	0	0	0	0	0	1	0	1	0	0	2	0	2	
NUMBER OBSERVATIONS		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

LEVEL NUMBER 7	FREQUENCY	11	2	2	2	0	0	1	1	0	0	0	0	1	0	0	0	0	0	1	3	
NUMBER OBSERVATIONS		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

FACTOR NUMBER 2

		GREATER THAN	LESS THAN OR EQUAL TO										AVERAGE WITHIN LEVEL										NO. OBS. PER LEVEL			
LEVEL 1			600000.000										243889.4375										254			
LEVEL 2		600000.000	1200000.000										868852.3750										231			
LEVEL 3		1200000.000	1800000.000										1444264.0000										238			
LEVEL 4		1800000.000											2063833.0000										238			

LEVEL NUMBER 1	FREQUENCY	18	2	1	1	2	7	1	0	0	1	2	0	0	0	0	0	0	0	2	5	
	NUMBER OBSERVATIONS	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

LEVEL NUMBER 2	FREQUENCY	12	2	7	1	1	2	5	4	0	0	0	0	0	2	1	1	1	1	0	2	
	NUMBER OBSERVATIONS	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

LEVEL NUMBER 3	FREQUENCY	14	3	0	2	3	0	2	1	3	2	2	3	2	1	1	0	1	1	0	1	0
	NUMBER OBSERVATIONS	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

LEVEL NUMBER 4	FREQUENCY	13	4	4	5	2	4	2	0	0	1	0	0	0	0	0	0	0	0	0	1	0
	NUMBER OBSERVATIONS	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

FACTOR NUMBER 3

		GREATER THAN	LESS THAN OR EQUAL TO	AVERAGE WITHIN LEVEL	NO. OBS. PER LEVEL
LEVEL 1			24.000	23.5055	432
LEVEL 2		24.000		24.6704	313

LEVEL NUMBER 1	FREQUENCY	29	7	4	1	2	3	5	0	2	4	2	1	2	1	1	1	1	1	1	3	13
	NUMBER OBSERVATIONS	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

LEVEL NUMBER 2	FREQUENCY	28	4	8	8	6	10	5	5	1	0	2	2	0	0	2	0	1	1	0	1	0
	NUMBER OBSERVATIONS	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

FACTOR NUMBER 4

		GREATER THAN	LESS THAN OR EQUAL TO	AVERAGE WITHIN LEVEL	NO. OBS. PER LEVEL
LEVEL 1			2.000	1.6027	449
LEVEL 2		2.000	3.500	2.6431	394
LEVEL 3		3.500		3.9642	102

LEVEL NUMBER 1	FREQUENCY	18	2	3	2	3	1	3	1	1	3	1	0	2	1	3	0	1	2	0	1	8
	NUMBER OBSERVATIONS	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

LEVEL NUMBER 2	FREQUENCY	6	4	7	5	2	8	5	2	1	1	2	2	0	0	0	1	1	0	1	3	5
	NUMBER OBSERVATIONS	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

LEVEL NUMBER 3	FREQUENCY	33	5	2	2	3	4	2	2	1	0	1	1	0	0	0	0	0	0	0	0	0
	NUMBER OBSERVATIONS	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20


```

C ***** SUBROUTINE GROOM(XX,TIDE,IK,NKEEP)
C
C SUBROUTINE GROOM ARRANGES THE TIDE VALUES AND THE CORRESPONDING
C XX VALUES IN STRICTLY ASCENDING ORDER.
C *****
C *****
      DIMENSION XX(2,16,100), TIDE(100), IAWAY(100)
101 FORMAT('1 TIDAL VALUE CUT CF ORDER')
      DO 110 I=1,IK
110 TIDE(I)=TIDE(I)-FLOAT(IFIX(TIDE(I)))
      DO 111 J=1,IK
        XLOW=1.1
      DO 112 I=J,IK
        IF(TIDE(I)-XLOW) 113,112,112
113 XLOW=TIDE(I)
        ILOW=I
112 CONTINUE
        SAVE=TIDE(J)
        TIDE(J)=TIDE(ILOW)
        TIDE(ILOW)=SAVE
      DO 114 I=1,16
        SAVE=XX(1,I,J)
        XX(1,I,J)=XX(1,I,ILOW)
114 XX(1,I,ILOW)=SAVE
111 CONTINUE
      KAWAY=0
      DO 220 I=2,IK
        IF(TIDE(I)-TIDE(I-1)) 219,221,220
221 KAWAY=KAWAY+1
        IAWAY(KAWAY)=I
220 CONTINUE
      NKEEP=IK -KAWAY
      ICOUNT=0
      JAWAY=1

```

```

DO 300 I=1,NKEEP
IF (I+ICOUNT-JAWAY(JAWAY)) 301,302,302
302 JAWAY=JAWAY+1
ICOUNT=ICOUNT+1
301 TIDE(I)=TIDE(I+ICOUNT)
DO 224 JI=1,16
XX(1,JI,I)=XX(1,JI,I+ICOUNT)
224 XX(2,JI,I)=XX(2,JI,I+ICOUNT)
300 CONTINUE
GO TO 99
219 WRITE(6,101)
99 RETURN
END

```

```

C** SUBROUTINE COUNT( XVALUE,XLIM1,XLIM2,ICOUNT)
C**
C SUBROUTINE COUNT COUNTS THE NUMBER OF DATA VALUES THAT ARE
C OUTSIDE OF THE PREDICTED CONFIDENCE LIMITS. ICOUNT=1 IF OUT OF
C LIMITS. ICOUNT=0 IF WITHIN LIMITS.
C**
C** ICOUNT=0
C** IF(XVALUE-XLIM1) 10,10,11
C** 11 IF(XLIM2-XVALUE) 10,12,12
C** 10 ICOUNT=1
C** 12 RETURN
C** END

```



```

C*****
C      SUBROUTINE LENGTH(XX,TIDE,XPOSIT,NKEEP)
C*****
C      SUBROUTINE LENGTH CALCULATES GO PROFILES THROUGH THE ESTUARY
C*****
C      FOR TIDAL PHASE OF 0.0, 0.25, 0.50, AND 0.75.
C*****
C*****
C      DIMENSION XX(2,16,100),TIDE(100),XPOSIT(16),SAVE(4,100),
C      1XX1(16),XX2(16),XX3(16),XX4(16),WORK(100),ARG(10),VAL(10)
C      1 FORMAT(' ',4F20.4)
C      2 FORMAT('100 VALUES THRU ESTUARY FOR FOUR TIDAL PHASES')
C      WRITE(6,2)
C      ACC=0.0001
C      DO 10 I=1,16
C*****
C      THE THIRD INDEX, AN INDEX ON TIDAL PHASE, MUST BE CHANGED WITH
C      DIFFERENT XX SETS IN THE FOLLOWING FOUR STATEMENTS TO
C      APPROXIMATE TIDAL PHASE VALUES OF 0.0, 0.25, 0.50, AND 0.75.
C*****
C*****
C      XX1(I)=XX(1,I,1)
C      XX2(I)=XX(1,I,16)
C      XX3(I)=XX(1,I,33)
C      XX4(I)=XX(1,I,48)
C      DO 11 I=1,100
C      X=0.2*FLOAT(I)
C      CALL ATSG(X,XPOSIT,XX1,WORK,16,1,ARG,VAL,10)
C      CALL ACFI(X,ARG,VAL,SAVE(1,I),10,ACC,IER)
C      CALL ATSG(X,XPOSIT,XX2,WORK,16,1,ARG,VAL,10)
C      CALL ACFI(X,ARG,VAL,SAVE(2,I),10,ACC,IER)
C      CALL ATSG(X,XPOSIT,XX3,WORK,16,1,ARG,VAL,10)
C      CALL ACFI(X,ARG,VAL,SAVE(3,I),10,ACC,IER)
C      CALL ATSG(X,XPOSIT,XX4,WORK,16,1,ARG,VAL,10)
C      CALL ACFI(X,ARG,VAL,SAVE(4,I),10,ACC,IER)
C      11

```

```
DO 12 I=1,100  
12 WRITE(6,1) (SAVE(J,I),J=1,4)  
RETURN  
END
```

```

C ***** SUBROUTINE TIMEX(XX,TIDE,NKEEP) *****
C
C ***** TIMEX CALCULATES CD PROFILES THROUGH THE TICAL PHASE FOR *****
C ***** STATIONS 1, 2, AND 3. *****
C *****
C *****
C ***** DIMENSION XX(2,16,100),TIDE(100),SAVE(3,100),XXX(100),XXY(100), *****
C ***** 1XXZ(100),III(3),WORK(100),ARG(10),VAL(10),II(3) *****
C ***** REAL III *****
C ***** 1 FORMAT(' ',ZF20.4) *****
C ***** 2 FORMAT('1.',LISTING OF OD VALUES THRU TICAL PHASE FOR THREE STATI *****
C ***** WRITE(6,2) *****
C ***** ACC=0.0001 *****
C *****
C ***** III MUST BE CHANGED FOR DIFFERENT XX SETS *****
C *****
C ***** III(1)=-1.1 *****
C ***** III(2)=-1.55 *****
C ***** III(3)=+1.48 *****
C *****
C ***** THE II VALUES, WHICH RELATE STATION NUMBER TO POSITION IN THE *****
C ***** ESTUARY, MUST BE CHANGED FOR DIFFERENT ESTUARIES. *****
C *****
C *****
C ***** II(1)=3 *****
C ***** II(2)=9 *****
C ***** II(3)=14 *****
C ***** DO 11 I=1,NKEEP *****
C ***** XXX(I)=XX(1,II(1),I) *****
C ***** XXY(I)=XX(1,II(2),I) *****
C ***** 11 XXZ(I)=XX(1,II(3),I) *****

```



```

DO 10 I=1,100
X=0.01*FLOAT(I)
CALL ATSG(X,TIDE,XXX,WORK,NKEEP,1,ARG,VAL,10)
CALL ACFI(X,ARG,VAL,SAVE(1,1),10,ACC,IER)
CALL ATSG(X,TIDE,XXY,WORK,NKEEP,1,ARG,VAL,10)
CALL ACFI(X,ARG,VAL,SAVE(2,1),10,ACC,IER)
CALL ATSG(X,TIDE,XXZ,WORK,NKEEP,1,ARG,VAL,10)
CALL ACFI(X,ARG,VAL,SAVE(3,1),10,ACC,IER)
10 DO 13 I=1,100
SAVE(1,I)=SAVE(1,I)+III(1)
SAVE(2,I)=SAVE(2,I)+III(2)
13 SAVE(3,I)=SAVE(3,I)+III(3)
DO 12 I=1,100
12 WRITE(6,1) (SAVE(J,I),J=1,3)
RETURN
END

```

```

C*** SUBROUTINE PREDIC(XYZ,NKEEP,J,TIDE,PHASE,XMEAN)
C***
C
C SUBROUTINE PREDIC TAKES THE OUTPUT FROM THE DIFFERENTIAL
C EQUATIONS PROGRAM AND DETERMINES A PREDICTED VALUE AT THE SAME
C TIME AND POSITION AS THE OBSERVED VALUE WHICH HAS JUST BEEN READ
C IN. AN INTERPOLATING ROUTINE IS USED TO DO THIS. XX, NKEEP,
C IPOSET, TIDE, AND PHASE ARE PASSED. XMEAN IS RETURNED.
C
C***
C DIMENSION XYZ(2,16,100),XZZ(100),TIDE(100),II(3),III(3),
C IWORK(100),ARG(10),VAL(10)
C COMMON JJ
C REAL III
C ACC=0.0001
C
C II MUST BE CHANGED IF THE OUTPUT POSITIONS ARE CHANGED IN THE
C DIFFERENTIAL EQUATIONS PROGRAM.
C
C***
C II(1)=3
C II(2)=9
C II(3)=14
C
C III MUST BE CHANGED FOR DIFFERENT XX SETS.
C
C***
C III(1)=-0.10
C III(2)=-0.55
C III(3)=+0.48
C IF(J-JJ) 8,18,8
C 8 DO 9 I=1,NKEEP
C 9 XZZ(I)=XYZ(1,II(J),I)

```

```
18 CALL ATSG(PHASE,TIDE,XZZ,WCRK,NKEEP,1,ARG,VAL,10)
   CALL ACFI(PHASE,ARG,VAL,XMEAN,10,ACC,IER)
   XMEAN=XMEAN+111(J)
   JJ=J
   RETURN
   END
```



```

SUBROUTINE LIMXXX(XMEAN,PHASE,IVECT,L)
DIMENSION PP(30),XLIM(20),IVECT(19),RESID(19),PA(30),DELTA(4)
COMMON RESID,RESI

```

```

1 FORMAT(' ',F10.4,19F6.2)

```

```

SAT=8.0

```

```

JHIGH=IFIX(SAT*10.0+1.5)

```

```

XR=1.0

```

```

XR=0.5

```

```

C *****
C DELTA MUST BE CHANGED FOR DIFFERENT ESTUARIES.
C *****

```

```

DELTA(1)=0.275

```

```

DELTA(2)=0.275

```

```

DELTA(3)=0.0475

```

```

PARA=XMEAN*DELTA(L)

```

```

C=1.0

```

```

IF(PARA-0.50) 91,92,92

```

```

C *****
C THE FOLLOWING STATEMENT IS THE CORRECTION TO THE CONVERTED
C POISSON CONFIDENCE LIMITS.
C *****

```

```

91 C=1.0-(0.5-PARA)*0.6

```

```

92 XMASS=0.001

```

```

PROB=0.0

```

```

ADD=1.0/EXP(PARA)

```

```

DO 10 I=1,30

```

```

X=FLUAT(I)

```

```

PROB=PROB+ADD

```

```

PA(I)=ADD

```

```

PP(I)=PROB

```

```

ADD=ADD*PARA/X

```

```

IF(ADD-XMASS) 11,11,10
10 CONTINUE
11 I=1
DO 70 J=1,19
XL=0.05*FLOAT(J)
52 IF(PP(I)-XL) 50,51,51
50 I=I+1
GO TO 52
51 IF(I-1) 53,53,54
54 X=(XL-PP(I-1))/ PA(I)
X=FLOAT(I)+X-1.5
GO TO 55
53 X=XL/ PA(I)-0.5
55 XLIM(J)=XMEAN-(PARA-X)*C
IF(PHASE-0.0001) 22,22,23
23 XLIM(J)=XR*XLIM(J)+(1.-XR)*RESID(J)
22 RESID(J)=XLIM(J)
XXX=XLIM(J)*10.0+1.5
JJ=FIX(XXX)
IF(JJ) 7,7,8
7 JJ=1
GO TO 12
8 IF(JJ-JHIGH) 12,12,9
9 JJ=JHIGH
12 IVECT(J)=JJ
70 CONTINUE
DO 71 J=1,9
IKEEP=IVECT(J)
XKEEP=XLIM(J)
IVECT(J)=IVECT(20-J)
XLIM(J)=XLIM(20-J)
IVECT(20-J)=IKEEP
71 XLIM(20-J)=XKEEP
WRITE(6,1) PHASE,(XLIM(J),J=1,19)
99 RETURN

```


END


```

GO TO 55
53 X=XL/ PA(1)-0.5
55 X1=XMEAN-(PARA-X)*C
56 IF(PP(I)-XH) 57,58,58
57 I=I+1
GO TO 56
58 X=1.0-PP(I)
X=(XL-X)/ PA(I)
X=1.0-X
X=FLOAT(I)+X-1.5
X2=XMEAN+(X-PARA)*C
RETURN
END

```

```

C** SUBROUTINE LIMITJ(XMEAN, X1, X2, J)
C**
C** SUBROUTINE LIMITS TAKES THE PREDICTED MEAN AND DETERMINES POISSON
C** CONFIDENCE LIMITS. THE POISSON VARIANCE IS CALCULATED BY THE
C** FORMULA VAR= MEAN*DELTA.
C**
C** DIMENSION DELTA(1), PP(30), PA(30)
C**
C** ALPHA CARDS SHOULD BE ROTATED UNTIL ALL LEVELS HAVE BEEN RUN.
C**
C** ALPHA=0.40
C** ALPHA=0.30
C** ALPHA=0.25
C** ALPHA=0.20
C** ALPHA=0.15
C** ALPHA=0.05
C** ALPHA=0.1
C** ALPHA=0.35
C** ALPHA=0.50
C** XL=ALPHA/2.0
C** XH=1.0-XL
C**
C** POTCMAC ESTUARY DELTA VALUES.
C**
C** DELTA(1)=0.275
C** DELTA(2)=0.275
C** DELTA(3)=0.0475
C** PARA=XMEAN*DELTA(J)
C** XMASS=0.001

```

```

PROB=0.0
ADD=1.0/EXP(PARA)
DO 10 I=1,30
X=FLOAT(I)
PROB=PROB+ADD
PA(I)=ADD
PP(I)=PROB
ADD=ADD*PARA/X
IF(ADD-XMASS) 11,11,10
10 CONTINUE
11 I=1
52 IF(PP(I)-XL) 50,51,51
50 I=I+1
GO TO 52
51 IF(I-1) 53,53,54
54 X=(XL-PP(I-1))/PA(I)
X=FLOAT(I)+X-1.5
GO TO 55
53 X=XL/PA(I)-0.5
55 X1=XMEAN-(PARA-X)
56 IF(PP(I)-XH) 57,58,58
57 I=I+1
GO TO 56
58 X=1.0-PP(I)
X=(XL-X)/PA(I)
X=1.0-X
X=FLOAT(I)+X-1.5
X2=XMEAN+(X-PARA)
RETURN
END

```



```

C*****
C      SUBROUTINE TIDAL(IMONTH,IDAY,TIME,XPHASE,PHASE)
C*****
C      SUBROUTINE TIDAL DETERMINES THE POINT IN TIDAL CYCLE USING THE
C      MONTH, DAY, AND TIME OF DAY. TIME IS PASSED HAVING MILITARY
C      VALUES, SUCH AS 1459 OR 1600. PHASE IS PASSED BACK RANGING FROM
C      0.0 TO 0.99999.
C*****
C      X=FLOAT(IFIX(TIME))
C      TIME=(X+(TIME-X)*100./60.)/100.
C*****
C      THE NEXT FOUR CARDS MUST BE CHANGED WITH DIFFERENT SURVEYS.
C      THE PRESENT CARDS ARE CODED FOR JUNE 20 AS THE FIRST DAY OF THE
C      SURVEY BEING CONSIDERED.
C*****
C      IF(IMONTH-6 ) 1,1,2
C      1 IDAY=IDAY-20
C      GO TO 3
C      2 IDAY=IDAY+10
C      3 PHASE=(FLOAT(IDAY)*24.+TIME-XPHASE)/12.4
C      PHASE=PHASE-FLOAT(IFIX(PHASE))
C      RETURN
C      END

```

```

SUBROUTINE TID12(IMONTH, IDAY, TIME, XPHASE, PHASE)
  ITIME=TIME
  XTIME=TIME-ITIME
  XTIME=XTIME*100./60.
  TIME=ITIME
  TIME=TIME+XTIME
  THE FOLLOWING FOUR STATEMENTS MUST BE CHANGED IF THE FIRST DAY
    OF THE SURVEY OF INTEREST IS DIFFERENT FROM JUNE 20.
  IF(IMONTH-6 ) 1,1,2
1 IDAY=IDAY-20
  GO TO 3
2 IDAY=IDAY+10
3 PHASE=(FLOAT(IDAY)*24.+TIME-XPHASE)/12.4
  IPHASE=PHASE
  PHASE=PHASE-IPHASE
  PHASE=PHASE*12.
  RETURN
  END

```

C
C

*
*

SUBROUTINE ATSG(X,Z,F,WORK,IROW,ICOL,ARG,VAL,NDIM)

SUBROUTINE ATSG

PURPOSE

NDIM POINTS OF A GIVEN GENERAL TABLE ARE SELECTED AND ORDERED SUCH THAT $ABS(ARG(I)-X) \cdot GE \cdot ABS(ARG(J)-X)$ IF $I.GT.J$.

USAGE

CALL ATSG (X,Z,F,WORK,IROW,ICOL,ARG,VAL,NDIM)

DESCRIPTION OF PARAMETERS

X	- THE SEARCH ARGUMENT.
Z	- THE VECTOR OF ARGUMENT VALUES (DIMENSION IROW).
F	- IN CASE ICOL=1, F IS THE VECTOR OF FUNCTION VALUES (DIMENSION IROW).
	IN CASE ICOL=2, F IS AN IROW BY 2 MATRIX. THE FIRST COLUMN SPECIFIES THE VECTOR OF FUNCTION VALUES AND THE SECOND THE VECTOR OF DERIVATIVES.
WORK	- A WORKING STORAGE (DIMENSION IROW).
IROW	- THE DIMENSION OF VECTORS Z AND WORK AND OF EACH COLUMN IN MATRIX F.
ICOL	- THE NUMBER OF COLUMNS IN F (I.E. 1 OR 2).
ARG	- THE RESULTING VECTOR OF SELECTED AND ORDERED ARGUMENT VALUES (DIMENSION NDIM).
VAL	- THE RESULTING VECTOR OF SELECTED FUNCTION VALUES (DIMENSION NDIM) IN CASE ICOL=1. IN CASE ICOL=2, VAL IS THE VECTOR OF FUNCTION AND DERIVATIVE VALUES (DIMENSION 2*NDIM) WHICH ARE STORED IN PAIRS (I.E. EACH FUNCTION VALUE IS FOLLOWED BY ITS DERIVATIVE VALUE).
NDIM	- THE NUMBER OF POINTS WHICH MUST BE SELECTED OUT OF THE GIVEN TABLE (Z,F).

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C GENERATION OF VECTOR WORK AND COMPUTATION OF ITS GREATEST ELEMENT.

```

3 B=0.
  DO 5 I=1,IROW
    DELTA=ABS(Z(I)-X)
    IF(DELTA-B)5,5,4
4 B=DELTA
5 WORK(I)=DELTA

```

C GENERATION OF TABLE (ARG,VAL)

```

B=B+1.
DO 10 J=1,N
  DELTA=B
  DO 7 I=1,IROW
    IF(WORK(I)-DELTA)6,7,7
6 II=I
  DELTA=WORK(I)
7 CONTINUE
  ARG(J)=Z(II)
  IF(ICOL-1)8,9,8
8 VAL(2*J-1)=F(II)
  III=II+IROW
  VAL(2*J)=F(III)
  GOTO 10
9 VAL(J)=F(III)
10 WORK(II)=B
11 RETURN
    END

```

SUBROUTINE ACFI(X,ARG,VAL,Y,NDIM,EPS,IER)

SUBROUTINE ACFI

PURPOSE

TO INTERPOLATE FUNCTION VALUE Y FOR A GIVEN ARGUMENT VALUE
X USING A GIVEN TABLE (ARG,VAL) OF ARGUMENT AND FUNCTION
VALUES.

USAGE

CALL ACFI (X,ARG,VAL,Y,NDIM,EPS,IER)

DESCRIPTION OF PARAMETERS

X - THE ARGUMENT VALUE SPECIFIED BY INPUT.
ARG - THE INPUT VECTOR (DIMENSION NDIM) OF ARGUMENT
VALUES OF THE TABLE (POSSIBLY DESTROYED).
VAL - THE INPUT VECTOR (DIMENSION NDIM) OF FUNCTION
VALUES OF THE TABLE (DESTROYED).
Y - THE RESULTING INTERPOLATED FUNCTION VALUE.
NDIM - AN INPUT VALUE WHICH SPECIFIES THE NUMBER OF
POINTS IN TABLE (ARG,VAL).
EPS - AN INPUT CONSTANT WHICH IS USED AS UPPER BOUND
FOR THE ABSOLUTE ERROR.
IER - A RESULTING ERROR PARAMETER.

REMARKS

- (1) TABLE (ARG,VAL) SHOULD REPRESENT A SINGLE-VALUED
FUNCTION AND SHOULD BE STORED IN SUCH A WAY, THAT THE
DISTANCES $ABS(ARG(I)-X)$ INCREASE WITH INCREASING
SUBSCRIPT I. TO GENERATE THIS ORDER IN TABLE (ARG,VAL),
SUBROUTINES ATSG, ATSM OR ATSE COULD BE USED IN A
PREVIOUS STAGE.
- (2) NO ACTION BESIDES ERROR MESSAGE IN CASE NDIM LESS

C
C
C
C
C

.....

```

DIMENSION ARG(NDIM),VAL(NDIM)
IFR=2
IF(NDIM)20,20,1
1 Y=VAL(1)
DELT2=0.
IF(NDIM-1)20,20,2

```

C
C

```

PREPARATIONS FOR INTERPOLATION LOOP
2 P2=1.
P3=Y
Q2=0.
Q3=1.

```

C
C
C

```

START INTERPOLATION LOOP
DO 16 I=2,NDIM
II=0
P1=P2
P2=P3
Q1=Q2
Q2=Q3
Z=Y
DELT1=DELT2
JEND=I-1

```

C
C

```

COMPUTATION OF INVERTED DIFFERENCES
3 AUX=VAL(I)
DO 13 J=1,JEND
H=VAL(I)-VAL(J)
IF(ABS(H)-1.E-6+ABS(VAL(I)))4,4,9

```



```

C
C
4 IF(ARG(I)-ARG(J))5,17,5
5 IF(J-JEND)8,6,6
C
C
6 INTERCHANGE ROW I WITH ROW I+II
  II=II+1
  III=I+II
  IF(III-NDIM)7,7,19
7 VAL(I)=VAL(III)
  VAL(III)=AUX
  AUX=ARG(I)
  ARG(I)=ARG(III)
  ARG(III)=AUX
  GOTO 3
C
C
8 COMPUTATION OF VAL(I) IN CASE VAL(I)=VAL(J) AND J LESS THAN I-1
  VAL(I)=1.E75
  GOTO 10
C
C
9 COMPUTATION OF VAL(I) IN CASE VAL(I) NOT EQUAL TO VAL(J)
  VAL(I)=(ARG(I)-ARG(J))/H
10 CONTINUE
C
C
  INVERTED DIFFERENCES ARE COMPUTED
C
C
  COMPUTATION OF NEW Y
  P3=VAL(I)*P2+(X-ARG(I-1))*P1
  Q3=VAL(I)*Q2+(X-ARG(I-1))*Q1
  IF(Q3)11,12,11
11 Y=P3/Q3
  GOTO 13
12 Y=1.E75
13 DELT2=ABS(Z-Y)
  IF(DELT2-EPS)19,19,14
14 IF(I-8)16,15,15
15 IF(DELT2-DELT1)16,18,18
16 CONTINUE

```

```

C      END OF INTERPOLATION LOOP
C
C      RETURN
C
C      THERE ARE TWO IDENTICAL ARGUMENT VALUES IN VECTOR ARG
C      17 IER=3
C          RETURN
C
C      TEST VALUE DELT2 STARTS OSCILLATING
C      18 Y=Z
C          IER=1
C          RETURN
C
C      THERE IS SATISFACTORY ACCURACY WITHIN NDIM-1 STEPS
C      19 IER=0
C      20 RETURN
C          END

```

POTOMAC DATA INPUT

Sta.	Mo.	Day	Time	Temp.	D.O.
1	6	20	1500	82.399	4.919
1	6	20	1530	82.240	4.820
1	6	20	1600	82.099	4.739
1	6	20	1630	82.299	4.739
1	6	20	1700	82.399	5.559
1	6	20	1730	82.699	5.359
1	6	20	1800	82.699	5.919
1	6	20	1830	82.690	6.030
1	6	20	1900	82.699	6.159
1	6	20	1930	82.699	6.519
1	6	20	2000	82.699	6.019
1	6	20	2030	82.500	6.039
1	6	20	2100	82.599	6.059
1	6	20	2130	82.640	6.300
1	6	20	2200	82.699	6.559
1	6	20	2230	82.399	6.699
1	6	20	2300	82.599	6.559
1	6	20	2330	82.390	6.490
1	6	21		82.199	6.439
1	6	21	30	82.199	6.339
1	6	21	100	82.000	6.179
1	6	21	130	82.000	6.259
1	6	21	200	82.000	6.039
1	6	21	230	82.000	5.859
1	6	21	300	82.099	5.699
1	6	21	330	82.199	5.679
1	6	21	400	82.000	6.399
1	6	21	430	81.699	5.959
1	6	21	500	81.899	5.339
1	6	21	530	81.899	5.319
1	6	21	600	81.599	5.000
1	6	21	630	81.540	5.030
1	6	21	700	81.500	5.059
1	6	21	730	81.899	4.939
1	6	21	800	81.899	4.959
1	6	21	830	81.699	4.159
1	6	21	900	81.630	4.650
1	6	21	930	81.560	5.150
1	6	21	1000	81.500	5.650
1	6	21	1030	81.399	5.939

Sta.	Mo.	Day	Time	Temp.	D.O.
1	6	21	1100	81.500	5.959
1	6	21	1130	81.399	6.259
1	6	21	1200	81.599	6.439
1	6	21	1230	81.699	6.559
1	6	21	1300	81.699	7.539
1	6	21	1330	82.199	7.259
1	6	21	1400	82.599	8.439
1	6	21	1430	82.699	8.819
1	6	21	1500	82.399	8.659
1	6	21	1530	82.299	6.979
1	6	21	1600	81.899	7.639
1	6	21	1630	81.699	7.159
1	6	21	1700	82.199	7.559
1	6	21	1730	82.699	7.939
1	6	21	1800	82.599	7.939
1	6	21	1830	82.399	7.579
1	6	21	1900	82.500	6.879
1	6	21	1930	82.599	7.919
1	6	21	2000	82.799	7.959
1	6	21	2030	82.599	7.859
1	6	21	2100	82.899	7.899
1	6	21	2130	82.899	7.639
1	6	21	2200	83.000	7.599
1	6	21	2230	82.899	7.500
1	6	21	2300	83.199	7.719
1	6	21	2330	82.799	7.039
1	6	22		82.599	7.139
1	6	22	30	82.899	8.039
1	6	22	100	83.000	8.179
1	6	22	130	82.899	8.379
1	6	22	200	82.899	7.899
1	6	22	230	83.000	7.779
1	6	22	300	82.299	7.399
1	6	22	330	81.899	6.839
1	6	22	400	81.799	6.139
1	6	22	430	81.699	5.579
1	6	22	500	81.899	6.399
1	6	22	530	81.899	6.179
1	6	22	600	81.899	6.659
1	6	22	630	82.399	7.259

Sta.	Mo.	Day	Time	Temp.	D.O.
1	6	22	700	82.299	7.339
1	6	22	730	82.299	6.459
1	6	22	800	82.099	6.139
1	6	22	830	82.199	7.179
1	6	22	900	82.500	7.259
1	6	22	930	82.299	6.859
1	6	22	1000	82.299	7.339
1	6	22	1030	82.399	7.639
1	6	22	1100	82.500	7.719
1	6	22	1130	82.500	7.859
1	6	22	1200	82.399	7.859
1	6	22	1230	82.599	8.000
1	6	22	1300	82.599	7.879
1	6	22	1330	82.899	8.500
1	6	22	1400	82.899	8.199
1	6	22	1430	82.699	7.159
1	6	22	1500	83.000	7.899
1	6	22	1530	83.199	6.479
1	6	22	1600	82.899	7.579
1	6	22	1630	82.899	7.759
1	6	22	1700	82.299	7.000
1	6	22	1730	82.399	7.199
1	6	22	1800	82.599	7.219
1	6	22	1830	82.699	7.579
1	6	22	1900	82.699	7.279
1	6	22	1930	82.699	6.079
1	6	22	2000	82.599	7.079
1	6	22	2030	82.500	6.819
1	6	22	2100	82.299	6.559
1	6	22	2130	82.399	6.000
1	6	22	2200	82.500	6.279
1	6	22	2230	82.699	6.579
1	6	22	2300	82.599	6.639
1	6	22	2330	82.399	6.479
1	6	23		82.199	5.259
1	6	23	30	82.099	6.279
1	6	23	100	82.099	6.339
1	6	23	130	82.199	5.379
1	6	23	200	82.000	6.279
1	6	23	230	82.000	6.259

Sta.	Mo.	Day	Time	Temp.	D.O.
1	6	23	300	81.799	6.279
1	6	23	330	81.799	6.259
1	6	23	400	81.799	6.239
1	6	23	430	81.799	6.039
1	6	23	500	81.799	5.879
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1	6	23	600	81.799	5.699
1	6	23	630	81.699	5.459
1	6	23	700	81.699	5.399
1	6	23	730	81.799	5.599
1	6	23	800	82.000	5.699
1	6	23	830	81.799	5.719
1	6	23	900	81.899	5.419
1	6	23	930	83.399	7.899
1	6	23	1000	81.699	5.039
1	6	23	1030	82.099	5.079
1	6	23	1100	82.099	6.519
1	6	23	1130	82.500	6.779
1	6	23	1200	82.599	6.779
1	6	23	1230	82.399	6.679
1	6	23	1300	82.899	6.899
1	6	23	1330	83.000	7.039
1	6	23	1400	83.199	7.139
1	6	23	1430	83.500	5.659
1	6	23	1500	83.500	7.659
1	6	23	1530	83.199	7.539
1	6	23	1600	83.699	8.319
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1	6	23	1730	83.000	6.559
1	6	23	1800	82.599	6.119
1	6	23	1830	82.199	4.659
1	6	23	1900	82.500	6.059
1	6	23	1930	82.899	6.239
1	6	23	2000	82.899	6.479
1	6	23	2030	82.899	6.799
1	6	23	2100	82.899	6.579
1	6	23	2130	83.000	5.259
1	6	23	2200	82.799	6.419
1	6	23	2230	82.500	6.099

Sta.	Mo.	Day	Time	Temp.	D.O.
1	6	23	2300	82.500	6.079
1	6	23	2330	82.699	6.939
1	6	24		82.599	7.219
1	6	24	30	82.500	7.159
1	6	24	100	82.500	7.039
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1	6	24	630	82.699	7.019
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1	6	24	900	82.899	7.000
1	6	24	930	82.899	6.839
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1	6	24	1430	83.599	8.559
1	6	24	1500	84.199	8.979
1	6	24	1530	83.899	9.299
1	6	24	1600	83.899	8.919
1	6	24	1630	83.500	8.779
1	6	24	1700	83.199	7.799
1	6	24	1730	83.199	8.039
1	6	24	1800	83.299	8.299
1	6	24	1830	83.099	8.000

Sta.	Mo.	Day	Time	Temp.	D.O.
1	6	24	1900	83.099	7.679
1	6	24	1930	82.899	7.539
1	6	24	2000	83.299	8.079
1	6	24	2030	83.399	8.459
1	6	24	2100	83.299	8.439
1	6	24	2130	83.500	8.559
1	6	24	2200	83.699	8.699
1	6	24	2230	83.500	8.399
1	6	24	2300	83.299	7.879
1	6	24	2330	82.799	6.579
1	6	25		82.899	7.819
1	6	25	30	83.000	7.859
1	6	25	100	83.299	6.659
1	6	25	130	83.199	7.859
1	6	25	200	83.500	7.779
1	6	25	230	83.299	8.719
1	6	25	300	83.399	8.000
1	6	25	330	83.500	7.539
1	6	25	400	83.699	7.359
1	6	25	430	83.299	7.159
1	6	25	500	83.699	7.319
1	6	25	530	83.799	7.179
1	6	25	600	83.500	6.779
1	6	25	630	83.299	6.959
1	6	25	700	83.199	6.139
1	6	25	730	83.199	5.839
1	6	25	800	82.899	6.439
1	6	25	830	82.899	6.539
1	6	25	900	83.199	6.419
1	6	25	930	83.500	5.539
1	6	25	1000	83.699	6.079
1	6	25	1030	84.299	6.739
1	6	25	1100	83.899	6.179
1	6	25	1130	83.799	5.899
1	6	25	1200	84.099	5.939
1	6	25	1230	84.500	6.479
1	6	25	1300	84.699	6.379
1	6	25	1330	85.199	6.659
1	6	25	1400	85.000	6.399
1	6	25	1430	85.299	6.699

Sta.	Mo.	Day	Time	Temp.	D.O.
1	6	25	1500	85.399	7.000
1	6	25	1530	85.699	7.119
1	6	25	1600	85.500	6.899
1	6	25	1630	85.399	7.039
1	6	25	1700	84.899	6.639
1	6	25	1730	85.199	7.079
1	6	25	1800	85.199	7.639
1	6	25	1830	84.699	6.459
1	6	25	1900	84.299	5.739
1	6	25	1930	84.000	5.779
1	6	25	2000	84.000	6.019
1	6	25	2030	84.199	6.059
1	6	25	2100	83.899	5.959
1	6	25	2130	83.799	5.859
1	6	25	2200	83.899	5.859
1	6	25	2230	83.599	5.739
1	6	25	2300	83.399	5.619
1	6	25	2330	83.299	5.839
1	6	26		83.299	5.619
1	6	26	30	83.500	5.539
1	6	26	100	83.199	5.779
1	6	26	130	83.399	5.899
1	6	26	200	83.099	5.699
1	6	26	230	83.399	5.779
1	6	26	300	83.299	5.799
1	6	26	330	83.299	5.759
1	6	26	400	83.099	5.859
1	6	26	430	83.299	5.979
1	6	26	500	83.399	5.959
1	6	26	530	83.399	5.979
1	6	26	600	83.399	6.039
1	6	26	630	83.500	5.979
1	6	26	700	83.299	5.979
1	6	26	730	83.099	5.879
1	6	26	800	83.000	5.859
1	6	26	830	83.000	5.679
1	6	26	900	82.899	5.859
1	6	26	930	83.000	5.779
1	6	26	1000	83.099	6.799
1	6	26	1030	83.199	5.659

Sta.	Mo.	Day	Time	Temp.	D.O.
1	6	26	1100	83.500	5.759
1	6	26	1130	83.799	5.939
1	6	26	1200	84.199	6.299
1	6	26	1230	84.000	6.539
1	6	26	1300	84.399	5.739
1	6	26	1330	84.299	6.579
1	6	26	1400	84.399	6.139
1	6	26	1430	84.399	5.699
1	6	26	1500	84.450	5.850
1	6	26	1530	84.500	6.019
1	6	26	1600	84.450	6.710
1	6	26	1630	84.399	7.419
1	6	26	1700	84.399	7.319
1	6	26	1730	84.299	7.759
1	6	26	1800	84.399	8.019
1	6	26	1830	83.899	8.419
1	6	26	1900	83.699	8.259
1	6	26	1930	83.500	6.299
1	6	26	2000	83.500	6.399
1	6	26	2030	83.299	6.239
1	6	26	2100	83.500	6.359
1	6	26	2130	83.500	6.639
1	6	26	2200	83.299	6.500
1	6	26	2230	83.099	6.039
1	6	26	2300	83.000	6.299
1	6	26	2330	82.799	6.419
1	6	27		82.699	6.379
1	6	27	30	82.500	6.279
1	6	27	100	82.500	6.879
1	6	27	130	82.299	7.439
1	6	27	200	82.299	6.579
1	6	27	230	82.199	6.539
1	6	27	300	82.199	6.519
1	6	27	330	82.199	6.459
1	6	27	400	82.440	6.370
1	6	27	430	82.699	6.299
1	6	27	500	82.699	6.219
1	6	27	530	82.699	6.159
1	6	27	600	82.699	6.179
1	6	27	630	82.899	6.099

Sta.	Mo.	Day	Time	Temp.	D.O.
1	6	27	700	82.699	6.059
1	6	27	730	82.899	6.059
1	6	27	800	82.799	6.139
1	6	27	830	82.799	6.099
1	6	27	900	82.899	6.039
1	6	27	930	83.000	6.079
1	6	27	1000	83.099	6.019
1	6	27	1030	82.899	5.939
1	6	27	1100	82.799	5.939
1	6	27	1130	83.099	6.059
1	6	27	1200	83.199	5.939
1	6	27	1230	83.099	6.000
1	6	27	1300	82.899	5.699
1	6	27	1330	83.099	5.739
1	6	27	1400	82.799	5.679
1	6	27	1430	82.899	5.659
1	6	27	1500	82.899	5.699
1	6	27	1530	82.899	5.919
1	6	27	1600	82.699	6.039
1	6	27	1630	82.500	6.239
1	6	27	1700	82.399	6.219
1	6	27	1730	82.699	6.739
1	6	27	1800	82.399	6.539
1	6	27	1830	82.199	6.559
1	6	27	1900	82.000	6.439
1	6	27	1930	82.000	6.539
1	6	27	2000	82.000	6.610
1	6	27	2030	82.000	6.699
1	6	27	2100	81.899	6.279
1	6	27	2130	81.899	6.419
1	6	27	2200	81.699	6.239
1	6	27	2230	81.500	6.339
1	6	27	2300	81.500	6.879
1	6	27	2330	81.399	6.859
1	6	28		81.399	6.839
1	6	28	30	81.199	6.819
1	6	28	100	81.199	6.779
1	6	28	130	80.899	6.739
1	6	28	200	80.899	6.599
1	6	28	230	80.699	6.359

Sta.	Mo.	Day	Time	Temp.	D.O.
1	6	28	300	80.899	6.619
1	6	28	330	80.599	6.759
1	6	28	400	80.699	6.539
1	6	28	430	80.599	6.419
1	6	28	500	80.799	6.419
1	6	28	530	80.699	6.539
1	6	28	600	80.799	6.439
1	6	28	630	80.899	6.439
1	6	28	700	81.299	6.439
1	6	28	730	80.899	6.279
1	6	28	800	81.000	6.359
1	6	28	830	81.299	6.259
1	6	28	900	81.299	6.479
1	6	28	930	81.299	6.279
1	6	28	1000	81.000	6.099
1	6	28	1030	81.099	6.299
1	6	28	1100	81.500	6.839
1	6	28	1130	81.500	6.759
1	6	28	1200	81.500	6.579
1	6	28	1230	81.699	6.279
1	6	28	1300	81.500	6.299
1	6	28	1330	81.599	6.439
1	6	28	1400	81.899	6.739
1	6	28	1430	81.500	6.000
1	6	28	1500	81.500	6.000
1	6	28	1530	81.500	5.879
1	6	28	1600	81.500	5.899
1	6	28	1630	82.099	7.259
1	6	28	1700	82.000	7.000
1	6	28	1730	82.000	7.739
1	6	28	1800	81.899	7.939
1	6	28	1830	81.899	8.000
1	6	28	1900	81.500	6.959
1	6	28	1930	81.500	7.500
1	6	28	2000	81.299	6.899
1	6	28	2030	81.500	6.799
1	6	28	2100	81.399	6.699
1	6	28	2130	81.199	8.639
1	6	28	2200	81.199	6.439
1	6	28	2230	81.399	6.399

Sta.	Mo.	Day	Time	Temp.	D.O.
1	6	28	2300	80.899	6.299
1	6	28	2330	80.799	6.279
1	6	29		80.899	6.079
1	6	29	30	80.899	6.000
1	6	29	100	80.599	6.500
1	6	29	130	80.699	5.939
1	6	29	200	80.599	6.039
1	6	29	230	80.299	6.079
1	6	29	300	80.399	6.099
1	6	29	330	80.500	6.099
1	6	29	400	80.000	5.919
1	6	29	430	80.099	5.959
1	6	29	500	79.899	5.939
1	6	29	530	80.000	6.079
1	6	29	600	80.000	6.379
1	6	29	630	80.199	6.539
1	6	29	700	80.000	6.559
1	6	29	730	80.199	6.599
1	6	29	800	80.199	6.479
1	6	29	830	80.199	6.519
1	6	29	900	80.199	6.459
1	6	29	930	80.199	6.399
1	6	29	1000	80.000	6.639
1	6	29	1030	80.199	6.699
1	6	29	1100	80.099	6.419
1	6	29	1130	80.199	6.859
1	6	29	1200	80.199	6.699
1	6	29	1230	80.099	6.659
1	6	29	1300	80.199	6.739
1	6	29	1330	80.399	6.859
1	6	29	1400	80.500	6.759
1	6	29	1430	80.590	6.750
1	6	29	1500	80.699	6.759
1	6	29	1530	80.699	6.279
1	6	29	1600	80.500	6.299
1	6	29	1630	80.699	6.259
1	6	29	1700	80.899	6.299
1	6	29	1730	81.000	6.339
1	6	29	1800	81.099	6.359
1	6	29	1830	81.199	6.299

Sta.	Mo.	Day	Time	Temp.	D.O.
1	6	29	1900	80.899	6.099
1	6	29	1930	80.799	5.919
1	6	29	2000	80.699	6.419
1	6	29	2030	80.799	6.199
1	6	29	2100	80.799	6.019
1	6	29	2130	80.599	5.779
1	6	29	2200	80.699	5.819
1	6	29	2230	80.699	5.839
1	6	29	2300	80.500	5.779
1	6	29	2330	80.599	5.779
1	6	30		80.500	5.679
1	6	30	30	80.399	5.659
1	6	30	100	80.500	5.599
1	6	30	130	80.199	5.579
1	6	30	200	80.199	5.399
1	6	30	230	80.199	5.619
1	6	30	300	80.199	5.679
1	6	30	330	80.299	5.739
1	6	30	400	80.000	5.579
1	6	30	430	80.000	5.199
1	6	30	500	80.199	5.199
1	6	30	530	80.000	5.379
1	6	30	600	80.000	5.419
1	6	30	630	80.000	5.419
1	6	30	700	80.099	5.279
1	6	30	730	79.799	8.359
1	6	30	800	79.799	5.459
1	6	30	830	79.699	5.139
1	6	30	900	79.899	5.479
1	6	30	930	79.699	5.500
1	6	30	1000	79.500	5.519
1	6	30	1030	79.699	5.619
1	6	30	1100	79.799	5.479
1	6	30	1130	79.799	5.099
1	6	30	1200	79.799	5.239
1	6	30	1230	79.899	4.959
1	6	30	1300	79.699	5.139
1	6	30	1330	79.699	5.159
1	6	30	1400	79.699	5.059
1	6	30	1430	80.199	5.819

Sta.	Mo.	Day	Time	Temp.	D.O.
1	6	30	1500	79.799	5.779
1	6	30	1530	80.000	6.000
1	6	30	1600	80.000	5.659
1	6	30	1630	79.899	5.639
1	6	30	1700	80.399	5.859
1	6	30	1730	80.000	5.339
1	6	30	1800	80.000	5.339
1	6	30	1830	80.199	5.419
1	6	30	1900	80.299	5.500
1	6	30	1930	80.500	5.699
1	6	30	2000	80.299	5.379
1	6	30	2030	80.000	5.079
1	6	30	2100	80.000	5.079
1	6	30	2130	80.000	4.979
1	6	30	2200	80.000	4.879
1	6	30	2230	80.000	4.879
1	6	30	2300	79.699	4.639
1	6	30	2330	79.799	4.699
1	7	1		79.899	4.939
1	7	1	30	80.000	4.879
1	7	1	100	80.000	4.859
1	7	1	130	79.799	4.779
1	7	1	200	79.699	4.679
1	7	1	230	79.799	4.959
1	7	1	300	79.799	4.539
1	7	1	330	79.899	4.359
1	7	1	400	79.899	5.079
1	7	1	430	79.500	5.159
1	7	1	500	79.799	4.899
1	7	1	530	79.500	4.979
1	7	1	600	79.699	5.039
1	7	1	630	79.799	4.979
1	7	1	700	79.799	4.539
1	7	1	730	79.899	4.679
1	7	1	800	79.699	5.159
1	7	1	830	79.699	4.899
1	7	1	900	79.599	4.939
1	7	1	930	79.500	4.979
1	7	1	1000	79.500	5.500
1	7	1	1030	79.699	5.819

Sta.	Mo.	Day	Time	Temp.	D.O.
1	7	1	1100	79.690	5.680
1	7	1	1130	79.699	5.559
1	7	1	1200	79.699	5.019
1	7	1	1230	79.699	5.019
1	7	1	1300	79.799	5.699
1	7	1	1330	79.699	5.379
1	7	1	1400	79.799	5.839
1	7	1	1430	80.000	5.359
1	7	1	1500	80.199	6.199
1	7	1	1530	80.199	5.279
1	7	1	1600	80.899	5.979
1	7	1	1630	80.699	5.879
1	7	1	1700	80.699	5.719
1	7	1	1730	80.799	5.739
1	7	1	1800	80.500	5.379
1	7	1	1830	81.199	5.959
1	7	1	1900	80.799	5.619
1	7	1	1930	80.799	5.439
1	7	1	2000	80.699	5.359
1	7	1	2030	80.799	5.399
1	7	1	2100	80.599	5.259
1	7	1	2130	80.599	5.379
1	7	1	2200	80.500	5.319
1	7	1	2230	80.500	6.000
1	7	1	2300	80.399	5.059
1	7	1	2330	80.000	4.619
1	7	2		80.000	4.279
1	7	2	30	80.000	4.399
1	7	2	100	80.399	4.479
1	7	2	130	80.500	4.639
1	7	2	200	80.500	4.659
1	7	2	230	80.399	4.639
1	7	2	300	80.500	4.619
1	7	2	330	80.599	4.479
1	7	2	400	80.399	4.399
1	7	2	430	80.299	4.359
1	7	2	500	80.299	4.399
1	7	2	530	80.199	4.279
1	7	2	600	80.299	4.379
1	7	2	630	80.199	4.379

Sta.	Mo.	Day	Time	Temp.	D.O.
1	7	2	700	80.299	4.500
1	7	2	730	80.199	4.779
1	7	2	800	80.399	4.879
1	7	2	830	80.299	4.899
1	7	2	900	80.299	5.099
1	7	2	930	80.500	5.279
1	7	2	1000	80.699	5.319
1	7	2	1030	80.899	5.559
1	7	2	1100	80.699	5.639
1	7	2	1130	81.000	6.159
1	7	2	1200	81.199	5.919
1	7	2	1230	80.899	5.619
1	7	2	1300	81.299	5.779
1	7	2	1330	81.299	5.879
1	7	2	1400	81.699	5.939
1	7	2	1430	81.699	5.899
1	7	2	1500	81.899	5.939
1	7	2	1530	82.000	6.099
1	7	2	1600	81.899	5.779
1	7	2	1630	81.699	5.599
1	7	2	1700	81.699	5.500
1	7	2	1730	81.599	5.439
1	7	2	1800	81.599	5.139
1	7	2	1830	81.500	5.259
1	7	2	1900	81.899	5.219
1	7	2	1930	81.820	5.140
1	7	2	2000	81.740	5.070
1	7	2	2030	81.660	5.000
1	7	2	2100	81.599	4.939
1	7	2	2130	81.899	5.199
1	7	2	2200	81.599	4.979
1	7	2	2230	81.599	5.139
1	7	2	2300	81.199	5.319
1	7	2	2330	81.500	5.699
1	7	3		81.299	4.639
1	7	3	30	81.299	4.719
1	7	3	100	80.699	4.179
1	7	3	130	80.699	3.779
1	7	3	200	80.699	3.359
1	7	3	230	80.599	3.359

Sta.	Mo.	Day	Time	Temp.	D.O.
1	7	3	300	80.590	3.630
1	7	3	330	80.599	3.919
1	7	3	400	80.699	3.979
1	7	3	430	80.399	4.159
1	7	3	500	80.399	4.359
1	7	3	530	80.799	4.579
1	7	3	600	80.899	4.619
1	7	3	630	80.500	4.539
1	7	3	700	80.599	4.439
1	7	3	730	80.599	4.639
1	7	3	800	80.799	4.839
1	7	3	830	80.399	6.459
1	7	3	900	80.000	6.379
1	7	3	930	80.199	6.399
1	7	3	1000	80.299	6.619
1	7	3	1030	80.500	6.699
1	7	3	1100	80.699	5.899
1	7	3	1130	80.699	5.979
1	7	3	1200	80.399	6.500
1	7	3	1230	80.899	6.719
1	7	3	1300	80.699	6.459
1	7	3	1330	80.299	5.659
1	7	3	1400	80.299	5.579
1	7	3	1430	80.799	6.279
1	7	3	1500	80.399	5.799
1	7	3	1530	80.599	5.379
1	7	3	1600	80.699	5.639
1	7	3	1630	80.899	5.759
1	7	3	1700	80.899	5.579
1	7	3	1730	80.799	5.599
1	7	3	1800	81.299	5.639
1	7	3	1830	81.299	5.639
1	7	3	1900	81.299	5.679
1	7	3	1930	81.199	5.739
1	7	3	2000	81.399	6.299
1	7	3	2030	81.299	5.739
1	7	3	2100	81.399	5.759
1	7	3	2130	81.199	5.699
1	7	3	2200	81.199	5.579
1	7	3	2230	80.899	5.559

Sta.	Mo.	Day	Time	Temp.	D.O.
1	7	3	2300	80.899	5.579
1	7	3	2330	80.899	5.559
1	7	4		80.599	5.419
1	7	4	30	80.699	5.539
1	7	4	100	80.599	5.119
1	7	4	130	80.699	5.299
1	7	4	200	80.640	5.280
1	7	4	230	80.599	5.279
1	7	4	300	80.490	5.220
1	7	4	330	80.399	5.179
1	7	4	400	80.500	5.059
1	7	4	430	80.399	5.039
1	7	4	500	80.299	4.939
1	7	4	530	80.199	5.679
1	7	4	600	80.000	5.779
1	7	4	630	80.000	5.699
1	7	4	700	80.199	5.659
1	7	4	730	80.399	5.699
1	7	4	800	80.199	5.699
1	7	4	830	80.199	5.899
1	7	4	900	80.399	6.199
1	7	4	930	80.599	5.599
1	7	4	1000	80.699	5.679
1	7	4	1030	80.699	5.759
1	7	4	1100	80.899	5.839
1	7	4	1130	80.699	5.699
1	7	4	1200	80.899	5.619
1	7	4	1230	81.000	5.579
1	7	4	1300	81.099	5.779
1	7	4	1330	81.199	5.539
1	7	4	1400	81.299	5.519
1	7	4	1430	80.899	5.359
1	7	4	1500	80.899	5.099
1	7	4	1530	80.799	5.239
1	7	4	1600	81.299	5.759
1	7	4	1630	81.299	5.639
1	7	4	1700	81.199	5.679
1	7	4	1730	81.299	5.559
1	7	4	1800	81.299	5.839
1	7	4	1830	81.099	5.500

Sta.	Mo.	Day	Time	Temp.	D.O.
1	7	4	1900	80.799	5.519
1	7	4	1930	81.000	5.450
1	7	4	2000	80.899	5.399
1	7	4	2030	80.899	5.259
1	7	4	2100	80.799	5.299
1	7	4	2130	80.699	6.439
1	7	4	2200	80.699	6.139
1	7	4	2230	80.699	6.139
1	7	4	2300	80.699	6.099
1	7	4	2330	80.500	6.079
1	7	5		80.599	6.039
1	7	5	30	80.399	6.019
1	7	5	100	80.399	5.979
1	7	5	130	80.399	6.019
1	7	5	200	80.399	5.859
1	7	5	230	80.399	5.839
1	7	5	300	80.299	5.779
1	7	5	330	80.199	5.739
1	7	5	400	80.099	5.679
1	7	5	430	80.299	5.639
1	7	5	500	80.000	5.599
1	7	5	530	80.000	5.679
1	7	5	600	79.899	5.719
1	7	5	630	79.799	5.819
1	7	5	700	80.000	5.779
1	7	5	730	80.880	5.930
1	7	5	800	80.750	6.100
1	7	5	830	80.620	6.270
1	7	5	900	79.500	6.439
1	7	5	930	79.500	6.699
1	7	5	1000	79.500	6.739
1	7	5	1030	79.799	7.039
1	7	5	1100	79.740	7.030
1	7	5	1130	79.699	7.039
1	7	5	1200	80.000	7.239
1	7	5	1230	80.299	7.359
1	7	5	1300	80.699	7.539
1	7	5	1330	80.699	7.619
1	7	5	1400	80.500	7.379
1	7	5	1430	80.590	7.450

Sta.	Mo.	Day	Time	Temp.	D.O.
1	7	5	1500	80.699	7.539
1	7	5	1530	80.500	7.259
1	7	5	1600	80.299	7.139
1	7	5	1630	80.340	7.250
1	7	5	1700	80.399	7.379
1	7	5	1730	80.500	7.259
1	7	5	1800	80.399	6.939
1	7	5	1830	80.390	7.120
1	7	5	1900	80.399	7.319
1	7	5	1930	80.000	7.000
1	7	5	2000	79.899	6.939
1	7	5	2030	79.799	7.039
1	7	5	2100	79.699	7.119
1	7	5	2130	79.399	7.079
1	7	5	2200	79.500	7.279
1	7	5	2230	79.399	7.299
1	7	5	2300	78.899	7.299
1	7	5	2330	78.599	7.099
1	7	6		78.500	7.039
1	7	6	30	78.340	7.090
1	7	6	100	78.199	7.159
1	7	6	130	78.099	7.039
1	7	6	200	78.199	7.039
1	7	6	230	78.099	7.039
1	7	6	300	78.299	6.879
1	7	6	330	78.299	6.859
1	7	6	400	78.199	6.839
1	7	6	430	78.000	6.819
1	7	6	500	78.030	6.790
1	7	6	530	78.060	6.770
1	7	6	600	78.099	6.759
1	7	6	630	78.399	6.779
1	7	6	700	78.299	6.839
1	7	6	730	78.399	6.799
1	7	6	800	78.500	6.919
1	7	6	830	78.599	6.919
1	7	6	900	78.699	6.879
1	7	6	930	78.899	7.000
1	7	6	1000	78.899	7.079
1	7	6	1030	78.899	6.859

Sta.	Mo.	Day	Time	Temp.	D.O.
1	7	6	1100	79.000	7.019
1	7	6	1130	79.000	6.899
1	7	6	1200	78.899	6.979
1	7	6	1230	79.000	7.139
1	7	6	1300	79.000	7.259
1	7	6	1330	78.899	7.239
1	7	6	1400	79.000	7.699
1	7	6	1430	79.199	7.779
1	7	6	1500	78.899	7.639
1	7	6	1530	78.599	7.379
1	7	6	1600	78.500	7.099
1	7	6	1630	78.500	7.219
1	7	6	1700	78.699	7.339
1	7	6	1730	78.699	7.159
1	7	6	1800	78.799	7.259
1	7	6	1830	78.699	7.579
1	7	6	1900	78.399	7.319
1	7	6	1930	78.500	7.199
1	7	6	2000	78.250	7.180
1	7	6	2030	78.000	7.179
1	7	6	2100	78.199	7.239
1	7	6	2130	78.199	7.519
1	7	6	2200	78.000	7.559
1	7	6	2230	78.199	7.679
1	7	6	2300	78.099	7.799
1	7	6	2330	77.799	7.559
1	7	7		77.799	7.459
1	7	7	30	77.699	7.619
1	7	7	100	77.399	7.179
1	7	7	130	77.199	7.059
1	7	7	200	77.490	7.100
1	7	7	230	77.799	7.159
1	7	7	300	77.500	7.039
1	7	7	330	77.500	7.000
1	7	7	400	77.500	6.939
1	7	7	430	77.500	6.919
1	7	7	500	77.500	6.859
1	7	7	530	77.500	6.759
1	7	7	600	77.299	6.759
1	7	7	630	77.399	6.759

Sta.	Mo.	Day	Time	Temp.	D.O.
1	7	7	700	77.599	6.659
1	7	7	730	77.699	6.739
1	7	7	800	77.599	6.859
1	7	7	830	77.699	6.679
1	7	7	900	77.899	6.879
1	7	7	930	77.899	6.779
1	7	7	1000	78.000	6.959
1	7	7	1030	78.199	7.139
1	7	7	1100	78.299	6.899
1	7	7	1130	78.299	6.919
1	7	7	1200	78.299	6.859
1	7	7	1230	78.500	7.259
1	7	7	1300	78.500	7.299
1	7	7	1330	78.699	7.739
1	7	7	1400	78.599	7.599
1	7	7	1430	78.500	7.500
1	7	7	1500	78.599	7.439
1	7	7	1530	78.699	7.599
1	7	7	1600	78.599	7.539
1	7	7	1630	78.699	7.659
1	7	7	1700	78.599	7.539
1	7	7	1730	78.699	7.699
1	7	7	1800	78.699	7.619
1	7	7	1830	78.599	7.579
1	7	7	1900	78.500	7.399
1	7	7	1930	78.500	7.299
1	7	7	2030	78.099	7.139
1	7	7	2100	78.199	7.179
1	7	7	2130	78.199	7.139
1	7	7	2200	78.199	7.079
1	7	7	2230	78.099	7.199
1	7	7	2300	78.199	7.239
1	7	7	2330	77.899	7.299
1	7	8		78.000	7.259
1	7	8	30	77.799	7.359
1	7	8	100	77.899	7.199
1	7	8	130	77.699	7.179
1	7	8	200	77.599	7.079
1	7	8	230	77.699	6.959
1	7	8	300	77.699	7.000

Sta.	Mo.	Day	Time	Temp.	D.O.
1	7	8	330	77.699	6.959
1	7	8	400	77.799	7.099
1	7	8	430	77.699	6.879
1	7	8	500	77.740	6.850
1	7	8	530	77.799	6.839
1	7	8	600	77.799	6.799
1	7	8	630	77.699	7.259
1	7	8	700	77.599	6.779
1	7	8	730	77.500	6.759
1	7	8	800	77.699	6.779
1	7	8	830	77.799	6.879
1	7	8	900	77.899	6.879
1	7	8	930	77.950	6.820
1	7	8	1000	78.000	6.779
1	7	8	1030	78.000	6.759
1	7	8	1100	78.099	6.739
1	7	8	1130	78.099	6.739
1	7	8	1200	78.199	6.779
1	7	8	1230	78.299	6.779
1	7	8	1300	78.299	6.739
1	7	8	1330	78.199	6.739
1	7	8	1400	78.299	6.779
1	7	8	1430	78.299	6.839
1	7	8	1500	78.099	6.879
1	7	8	1530	78.199	6.939
1	7	8	1600	78.199	6.859
1	7	8	1630	78.199	6.819
1	7	8	1700	78.000	6.879
1	7	8	1730	78.199	6.759
1	7	8	1800	78.299	6.879
1	7	8	1830	78.199	6.639
1	7	8	1900	78.099	6.619
1	7	8	1930	78.000	6.399
1	7	8	2000	78.099	6.659
1	7	8	2030	77.899	6.379
1	7	8	2100	77.840	6.360
1	7	8	2130	77.799	6.359
1	7	8	2200	77.799	7.479
1	7	8	2230	77.799	6.539
1	7	8	2300	77.699	6.479

Sta.	Mo.	Day	Time	Temp.	D.O.
1	7	8	2330	77.699	6.539
1	7	9		77.699	6.579
1	7	9	30	77.599	6.479
1	7	9	100	77.500	6.359
1	7	9	130	77.399	6.239
1	7	9	200	77.699	6.299
1	7	9	230	77.699	6.319
1	7	9	300	77.899	6.379
1	7	9	330	77.799	6.159
1	7	9	400	77.899	6.199
1	7	9	430	77.899	6.239
1	7	9	500	77.899	6.339
1	7	9	530	77.799	6.159
1	7	9	600	77.799	6.139
1	7	9	630	77.799	6.179
1	7	9	700	77.799	6.059
1	7	9	730	77.799	6.099
1	7	9	800	77.699	6.159
1	7	9	830	77.899	6.279
1	7	9	900	78.099	6.239
1	7	9	930	77.899	6.299
1	7	9	1000	78.099	6.179
1	7	9	1030	78.299	6.219
1	7	9	1100	78.199	6.279
1	7	9	1130	78.500	6.339
1	7	9	1200	78.699	6.379
1	7	9	1230	78.699	6.599
1	7	9	1300	78.899	6.739
1	7	9	1330	79.000	6.439
1	7	9	1400	79.000	6.500
1	7	9	1430	79.399	6.699
1	7	9	1500	79.299	6.579
1	7	9	1530	79.899	7.079
1	7	9	1600	79.799	7.059
1	7	9	1630	79.500	6.539
1	7	9	1700	79.299	6.659
1	7	9	1730	79.500	6.679
1	7	9	1800	79.099	6.059
1	7	9	1830	78.899	5.959
1	7	9	1900	78.599	5.619

Sta.	Mo.	Day	Time	Temp.	D.O.
1	7	9	1930	78.799	5.979
1	7	9	2000	79.299	6.459
1	7	9	2030	79.299	6.419
1	7	9	2100	79.399	6.379
1	7	9	2130	79.299	6.359
1	7	9	2200	79.299	6.339
1	7	9	2230	80.000	7.099
1	7	9	2300	79.699	6.659
1	7	9	2330	79.500	6.500
1	7	10		79.699	6.659
1	7	10	30	79.899	6.939
1	7	10	100	79.799	7.039
1	7	10	130	80.099	7.399
1	7	10	200	80.000	7.239
1	7	10	230	80.199	7.459
1	7	10	300	80.000	7.199
1	7	10	330	80.000	7.379
1	7	10	400	80.099	7.399
1	7	10	430	79.699	7.119
1	7	10	500	79.399	6.519
1	7	10	530	79.199	6.079
1	7	10	600	78.899	5.899
1	7	10	630	79.000	6.359
1	7	10	700	79.199	5.939
1	7	10	730	78.899	5.759
1	7	10	800	79.000	5.939
1	7	10	830	78.899	5.599
1	7	10	900	79.199	6.059
1	7	10	930	79.399	6.139
1	7	10	1000	79.299	6.739
1	7	10	1030	79.299	6.979
1	7	10	1100	79.290	6.850
1	7	10	1130	79.299	6.739
1	7	10	1200	79.599	6.939
1	7	10	1230	79.500	6.699
1	7	10	1300	79.600	6.720
1	7	10	1330	79.699	6.759
1	7	10	1400	80.399	7.379
1	7	10	1430	80.540	6.860
1	7	10	1500	80.699	6.359

Sta.	Mo.	Day	Time	Temp.	D.O.
1	7	10	1530	80.399	7.679
1	7	10	1600	80.699	5.899
1	7	10	1630	80.760	5.860
1	7	10	1700	80.820	5.840
1	7	10	1730	80.899	5.819
1	7	10	1800	80.799	8.299
1	7	10	1830	80.500	6.439
1	7	10	1900	80.290	5.900
1	7	10	1930	80.099	5.379
1	7	10	2000	80.490	6.400
1	7	10	2030	80.899	7.439
1	7	10	2100	81.199	6.419
1	7	10	2130	81.099	6.000
1	7	10	2200	80.699	6.159
1	7	10	2230	80.899	6.079
1	7	10	2300	81.199	6.319
1	7	10	2330	80.899	6.059
1	7	11		80.500	6.079
1	7	11	30	81.000	6.259
1	7	11	100	81.199	6.979
1	7	11	130	81.799	6.659
1	7	11	200	81.399	6.959
1	7	11	230	81.500	7.299
1	7	11	300	81.699	7.079
1	7	11	330	81.699	8.179
1	7	11	400	82.199	8.059
1	7	11	430	82.199	6.539
1	7	11	500	81.500	7.339
1	7	11	530	80.699	5.739
1	7	11	600	80.399	5.579
1	7	11	630	80.799	6.859
1	7	11	700	80.699	6.099
1	7	11	730	80.399	5.659
1	7	11	800	80.590	5.810
1	7	11	830	80.790	5.970
1	7	11	900	80.990	6.130
1	7	11	930	81.190	6.290
1	7	11	1000	81.399	6.459
1	7	11	1030	81.199	6.359
1	7	11	1100	81.290	6.090

Sta.	Mo.	Day	Time	Temp.	D.O.
1	7	11	1130	81.399	5.839
1	7	11	1200	81.799	6.079
1	7	11	1230	81.599	5.939
1	7	11	1300	81.699	6.239
1	7	11	1330	81.899	5.959
1	7	11	1400	81.899	6.139
1	7	11	1430	82.399	6.179
1	7	11	1500	82.199	6.379
1	7	11	1530	83.000	5.439
1	7	11	1600	82.899	5.419
1	7	11	1630	82.399	5.199
1	7	11	1700	82.399	5.219
1	7	11	1730	82.199	7.279
1	7	11	1800	82.199	6.299
1	7	11	1830	81.899	5.819
1	7	11	1900	81.899	6.179
1	7	11	1930	80.899	4.679
1	7	11	2000	81.299	5.979
1	7	11	2030	81.399	5.699
1	7	11	2100	81.699	8.500
1	7	11	2130	82.099	6.239
1	7	11	2200	82.099	6.099
1	7	11	2230	82.299	6.619
1	7	11	2300	82.000	6.539
1	7	11	2330	81.899	4.899
1	7	12		82.099	6.059
1	7	12	30	81.799	6.079
1	7	12	100	81.699	6.059
1	7	12	130	82.399	6.639
1	7	12	200	82.199	6.099
1	7	12	230	82.000	6.379
1	7	12	300	82.000	6.379
1	7	12	330	82.000	5.679
1	7	12	400	82.000	5.699
1	7	12	430	82.000	5.779
1	7	12	500	82.000	6.299
1	7	12	530	82.000	6.299
1	7	12	600	82.399	5.699
1	7	12	630	82.299	6.099
1	7	12	700	82.399	5.299

Sta.	Mo.	Day	Time	Temp.	D.O.
1	7	12	730	82.299	6.000
1	7	12	800	82.000	6.199
1	7	12	830	81.799	5.439
1	7	12	900	82.000	5.239
1	7	12	930	82.199	5.639
1	7	12	1000	82.500	5.299
1	7	12	1030	82.699	5.959
1	7	12	1100	82.790	5.730
1	7	12	1130	82.899	5.519
1	7	12	1200	82.699	5.959
1	7	12	1230	83.199	5.059
1	7	12	1300	83.599	5.899
1	7	12	1330	83.699	6.000
1	7	12	1400	83.699	6.579
1	7	12	1430	83.630	6.320
1	7	12	1500	83.560	6.060
1	7	12	1530	83.500	5.819
1	7	12	1600	83.520	5.590
1	7	12	1630	83.550	5.370
1	7	12	1700	83.570	5.150
1	7	12	1730	83.599	4.959
1	7	12	1800	83.699	5.899
1	7	12	1830	83.699	5.979
1	7	12	1900	84.000	6.479
1	7	12	1930	84.090	6.130
1	7	12	2000	84.199	5.799
1	7	12	2030	84.199	5.699
1	7	12	2100	84.000	5.439
1	7	12	2130	84.299	6.199
1	7	12	2200	84.199	6.459
1	7	12	2230	84.350	6.170
1	7	12	2300	84.500	5.899
1	7	12	2330	84.899	6.299
1	7	13		84.890	6.230
1	7	13	30	84.899	6.179
1	7	13	100	84.890	6.140
1	7	13	130	84.890	6.120
1	7	13	200	84.899	6.099
1	7	13	230	85.199	6.119
1	7	13	300	84.899	6.019

Sta.	Mo.	Day	Time	Temp.	D.O.
1	7	13	330	84.899	6.039
1	7	13	400	85.000	6.059
1	7	13	430	84.899	5.799
1	7	13	500	84.699	5.859
1	7	13	530	84.699	5.279
1	7	13	600	84.740	5.480
1	7	13	630	84.799	5.699
1	7	13	700	84.899	5.679
1	7	13	730	84.699	5.639
1	7	13	800	84.899	5.779
1	7	13	830	84.899	5.939
1	7	13	900	84.699	5.599
1	7	13	930	84.899	5.699
1	7	13	1000	84.920	5.460
1	7	13	1030	84.950	5.230
1	7	13	1100	84.970	5.000
1	7	13	1130	85.000	4.779
1	7	13	1200	84.899	4.879
1	7	13	1230	84.890	4.960
1	7	13	1300	84.890	5.040
1	7	13	1330	84.899	5.139
1	7	13	1400	84.899	5.079
1	7	13	1430	85.099	5.379
1	7	13	1500	85.099	5.479
1	7	13	1530	84.899	5.439
1	7	13	1600	84.740	5.380
1	7	13	1630	84.599	5.339
1	7	13	1700	84.000	5.199
1	7	13	1730	83.899	5.139
1	7	13	1800	83.899	5.219
1	7	13	1830	83.699	6.899
1	7	13	1900	83.500	6.779
1	7	13	1930	83.299	6.479
1	7	13	2000	82.899	6.299
1	7	13	2030	83.000	6.639
1	7	13	2100	82.799	6.179
1	7	13	2130	83.000	4.899
1	7	13	2200	82.899	6.119
1	7	13	2230	82.799	5.939
1	7	13	2300	82.699	5.899

Sta.	Mo.	Day	Time	Temp.	D.O.
1	7	13	2330	82.500	6.279
1	7	14		82.299	6.279
1	7	14	30	82.399	4.779
1	7	14	100	82.299	5.839
1	7	14	130	81.899	4.979
1	7	14	200	81.890	4.970
1	7	14	230	81.899	4.979
1	7	14	300	81.899	4.899
1	7	14	330	82.000	4.899
1	7	14	400	81.899	4.859
1	7	14	430	81.890	4.860
1	7	14	500	81.899	4.879
1	7	14	530	81.699	5.039
1	7	14	600	81.699	6.139
1	7	14	630	81.699	5.939
1	7	14	700	81.699	5.039
1	7	14	730	81.899	4.979
1	7	14	800	81.699	5.059
1	7	14	830	81.690	5.040
1	7	14	900	81.699	5.039
1	7	14	930	81.699	5.159
1	7	14	1000	81.699	4.859
1	7	14	1030	81.699	5.019
1	7	14	1100	81.699	5.000
1	7	14	1130	81.500	4.979
1	7	14	1200	81.500	4.980
1	7	14	1230	81.500	5.000
1	7	14	1300	81.600	5.050
1	7	14	1330	81.699	5.099
1	7	14	1400	81.500	5.079
1	7	14	1430	81.599	5.179
1	7	14	1500	81.599	5.159
1	7	14	1530	81.500	4.939
1	7	14	1600	81.599	5.039
1	7	14	1630	81.500	5.000
1	7	14	1700	81.500	5.019
1	7	14	1730	81.500	5.010
1	7	14	1800	81.500	5.019
1	7	14	1830	81.199	5.059
1	7	14	1900	81.500	5.919

Sta.	Mo.	Day	Time	Temp.	D.O.
1	7	14	1930	81.500	4.959
1	7	14	2000	81.600	4.960
1	7	14	2030	81.699	4.979
1	7	14	2100	81.799	5.019
1	7	14	2130	81.699	5.000
1	7	14	2200	81.699	5.059
1	7	14	2230	81.500	4.919
1	7	14	2300	81.699	6.099
1	7	14	2330	81.500	6.479
1	7	15		81.599	4.979
1	7	15	30	81.500	6.079
1	7	15	100	81.399	4.839
1	7	15	130	81.399	6.579
1	7	15	200	81.000	5.000
1	7	15	230	80.899	5.259
1	7	15	300	80.799	4.899
1	7	15	330	80.500	4.979
1	7	15	400	80.500	4.979
1	7	15	430	80.399	5.239
1	7	15	500	80.340	5.130
1	7	15	530	80.299	5.039
1	7	15	600	80.199	5.039
1	7	15	630	80.199	7.199
1	7	15	700	80.000	5.059
1	7	15	730	79.899	6.079
1	7	15	800	80.000	5.899
1	7	15	830	79.500	5.899
1	7	15	900	79.500	4.899
1	7	15	930	79.500	5.859
1	7	15	1000	79.560	5.840
1	7	15	1030	79.630	5.820
1	7	15	1100	79.699	5.819
1	7	15	1130	79.500	5.759
1	7	15	1200	79.799	5.779
1	7	15	1230	79.699	5.699
1	7	15	1300	79.699	5.719
1	7	15	1330	79.699	5.679
1	7	15	1400	79.699	5.699
1	7	15	1430	79.740	5.780
1	7	15	1500	79.799	5.879

Sta.	Mo.	Day	Time	Temp.	D.O.
1	7	15	1530	80.000	5.879
1	7	15	1600	80.199	6.439
1	7	15	1630	79.899	5.879
1	7	15	1700	79.699	5.819
1	7	15	1730	80.000	5.919
1	7	15	1800	80.000	5.839
1	7	15	1830	80.000	5.850
1	7	15	1900	80.000	5.879
1	7	15	1930	79.799	5.779
1	7	15	2000	79.599	5.839
1	7	15	2030	79.699	5.859
1	7	15	2100	79.699	5.839
1	7	15	2130	79.699	5.879
1	7	15	2200	79.699	5.839
1	7	15	2230	79.699	5.839
1	7	15	2300	79.799	5.779
1	7	15	2330	79.699	5.779
1	7	16		79.699	5.839
1	7	16	30	79.699	5.759
1	7	16	100	79.399	5.639
1	7	16	130	79.500	5.699
1	7	16	200	79.500	5.679
1	7	16	230	79.500	5.699
1	7	16	300	79.399	5.739
1	7	16	330	79.399	5.699
1	7	16	400	79.699	5.759
1	7	16	430	79.500	5.759
1	7	16	500	79.500	5.599
1	7	16	530	79.899	5.759
1	7	16	600	79.799	5.719
1	7	16	630	79.699	5.739
1	7	16	700	79.599	5.619
1	7	16	730	79.699	5.699
1	7	16	800	79.699	5.719
1	7	16	830	79.699	5.619
1	7	16	900	79.500	6.019
1	7	16	930	79.699	5.719
1	7	16	1000	79.699	5.799
1	7	16	1030	79.699	5.719
1	7	16	1100	79.500	5.639

Sta.	Mo.	Day	Time	Temp.	D.O.
1	7	16	1130	79.299	5.659
1	7	16	1200	79.500	5.659
1	7	16	1230	79.500	5.619
1	7	16	1300	79.699	5.619
1	7	16	1330	79.500	5.599
1	7	16	1400	79.500	5.579
1	7	16	1430	79.699	5.659
1	7	16	1500	79.500	5.639
1	7	16	1530	79.500	7.179
1	7	16	1600	79.699	5.699
1	7	16	1630	79.699	5.779
1	7	16	1700	79.599	5.779
1	7	16	1730	79.799	5.939
1	7	16	1800	80.000	6.000
1	7	16	1830	80.000	6.179
1	7	16	1900	79.799	5.979
1	7	16	1930	79.799	6.519
1	7	16	2000	79.599	5.979
1	7	16	2030	79.299	6.779
1	7	16	2100	79.399	5.819
1	7	16	2130	79.099	5.799
1	7	16	2200	78.799	5.679
1	7	16	2230	79.099	5.759
1	7	16	2300	78.990	5.690
1	7	16	2330	78.899	5.639
1	7	17		78.799	5.759
1	7	17	30	78.899	5.739
1	7	17	100	78.899	6.399
1	7	17	130	78.799	5.559
1	7	17	200	78.799	5.559
1	7	17	230	78.699	5.539
1	7	17	300	78.799	5.479
1	7	17	330	78.500	5.639
1	7	17	400	78.500	5.459
1	7	17	430	78.699	5.459
1	7	17	500	78.699	5.500
1	7	17	530	78.799	5.539
1	7	17	600	78.990	5.570
1	7	17	630	79.199	5.619
1	7	17	700	79.399	5.539

Sta.	Mo.	Day	Time	Temp.	D.O.
1	7	17	730	79.099	5.519
1	7	17	800	79.500	5.519
1	7	17	830	79.340	5.500
1	7	17	900	79.199	5.500
1	7	17	930	79.199	5.479
1	7	17	1000	79.399	5.439
1	7	17	1030	79.500	5.500
1	7	17	1100	79.500	5.539
1	7	17	1130	78.699	5.399
1	7	17	1200	78.890	5.390
1	7	17	1230	79.100	5.390
1	7	17	1300	79.300	5.390
1	7	17	1330	79.500	5.399
1	7	17	1400	79.399	5.359
1	7	17	1430	79.500	5.439
1	7	17	1500	79.699	5.479
1	7	17	1530	79.500	5.459
1	7	17	1600	79.500	5.539
1	7	17	1630	79.699	5.479
1	7	17	1700	79.720	5.550
1	7	17	1730	79.760	5.630
1	7	17	1800	79.799	5.719
1	7	17	1830	79.599	5.599
1	7	17	1900	79.500	5.699
1	7	17	1930	79.399	5.579
1	7	17	2000	79.699	5.739
1	7	17	2030	79.699	5.759
1	7	17	2100	79.699	5.779
1	7	17	2130	79.699	5.839
1	7	17	2200	79.599	5.779
1	7	17	2230	79.599	5.739
1	7	17	2300	79.599	5.619
1	7	17	2330	79.199	5.479
1	7	18		79.000	5.259
1	7	18	30	79.099	5.439
1	7	18	100	79.000	5.939
1	7	18	130	78.899	5.399
1	7	18	200	78.899	5.279
1	7	18	230	78.899	5.319
1	7	18	300	78.899	5.299

Sta.	Mo.	Day	Time	Temp.	D.O.
1	7	18	330	78.899	5.279
1	7	18	400	79.299	5.299
1	7	18	430	78.899	5.339
1	7	18	500	79.000	5.279
1	7	18	530	79.199	5.359
1	7	18	600	79.290	5.330
1	7	18	630	79.399	5.319
1	7	18	700	79.500	5.239
1	7	18	730	79.699	5.439
1	7	18	800	79.699	5.279
1	7	18	830	79.899	5.319
1	7	18	900	80.000	5.899
1	7	18	930	80.000	7.000
1	7	18	1000	80.099	6.879
1	7	18	1030	80.000	6.959
1	7	18	1100	80.000	6.879
1	7	18	1130	80.100	6.870
1	7	18	1200	80.199	6.879
1	7	18	1230	80.140	6.820
1	7	18	1300	80.099	6.779
1	7	18	1330	80.099	6.779
1	7	18	1400	80.299	6.759
1	7	18	1430	80.199	6.659
1	7	18	1500	80.000	6.599
1	7	18	1530	80.000	6.590
1	7	18	1600	80.000	6.599
1	7	18	1630	80.000	6.639
1	7	18	1700	80.199	6.779
1	7	18	1730	80.199	6.819
1	7	18	1800	80.199	6.799
1	7	18	1830	79.899	6.679
1	7	18	1900	79.799	6.659
1	7	18	1930	79.799	6.979
1	7	18	2000	80.000	6.699
1	7	18	2030	79.899	6.739
1	7	18	2100	79.899	6.779
1	7	18	2130	80.099	6.939
1	7	18	2200	80.299	7.059
1	7	18	2230	80.500	7.039
1	7	18	2300	80.199	6.899

Sta.	Mo.	Day	Time	Temp.	D.O.
1	7	18	2330	80.299	6.879
1	7	19		80.199	6.839
1	7	19	30	80.099	6.739
1	7	19	100	80.000	6.679
1	7	19	130	80.000	6.659
1	7	19	200	80.000	6.579
1	7	19	230	79.699	6.579
1	7	19	300	79.699	6.419
1	7	19	330	79.799	6.459
1	7	19	400	79.699	6.379
1	7	19	430	79.699	6.279
1	7	19	500	79.699	6.339
1	7	19	530	79.690	6.350
1	7	19	600	79.699	6.379
1	7	19	630	79.899	6.339
1	7	19	700	79.899	6.339
1	7	19	730	80.000	6.259
1	7	19	800	80.099	6.319
1	7	19	830	80.199	6.379
1	7	19	900	80.299	6.339
1	7	19	930	80.399	6.299
1	7	19	1000	80.490	6.300
1	7	19	1030	80.599	6.319
1	7	19	1100	80.500	6.419
1	7	19	1130	80.799	6.379
1	7	19	1200	80.500	6.259
1	7	19	1230	81.000	6.500
1	7	19	1300	80.899	6.379
1	7	19	1330	80.899	6.379
1	7	19	1400	80.899	6.339
1	7	19	1430	80.500	6.259
1	7	19	1500	80.699	6.179
1	7	19	1530	80.899	6.339
1	7	19	1600	80.899	6.179
1	7	19	1630	80.899	6.259
1	7	19	1700	81.000	6.259
1	7	19	1730	80.500	6.259
1	7	19	1800	80.899	6.179
1	7	19	1830	81.000	6.299
1	7	19	1900	81.500	7.599

Sta.	Mo.	Day	Time	Temp.	D.O.
1	7	19	1930	81.699	6.539
1	7	19	2000	81.099	6.439
1	7	19	2030	80.899	6.379
1	7	19	2100	81.099	6.419
1	7	19	2130	80.699	6.279
1	7	19	2200	80.899	6.459
1	7	19	2230	81.099	6.579
1	7	19	2300	81.099	6.519
1	7	19	2330	81.199	6.579
1	7	20		80.899	6.500
1	7	20	30	80.899	6.519
1	7	20	100	81.000	6.479
1	7	20	130	81.199	6.439
1	7	20	200	81.199	6.379
1	7	20	230	80.699	6.179
1	7	20	300	80.699	6.059
1	7	20	330	80.699	6.000
1	7	20	400	80.500	5.919
1	7	20	430	80.500	5.959
1	7	20	500	80.500	5.959
1	7	20	530	80.540	5.890
1	7	20	600	80.599	5.839
1	7	20	630	80.699	5.819
1	7	20	700	80.799	5.879
1	7	20	730	80.899	5.839
1	7	20	800	80.840	5.760
1	7	20	830	80.799	5.699
1	7	20	900	81.000	5.699
1	7	20	930	81.299	5.659
1	7	20	1000	81.399	5.679
1	7	20	1030	81.500	5.659
1	7	20	1100	81.500	5.599
1	7	20	1130	81.500	5.579
1	7	20	1200	81.699	8.439
1	7	20	1230	81.699	5.500
1	7	20	1300	81.899	4.299
1	7	20	1330	81.950	4.900
1	7	20	1400	82.000	5.500
1	7	20	1430	81.950	5.470
1	7	20	1500	81.899	5.459

Sta.	Mo.	Day	Time	Temp.	D.O.
1	7	20	1530	81.899	5.339
1	7	20	1600	81.890	5.370
1	7	20	1630	81.899	5.419
1	7	20	1700	81.890	5.320
1	7	20	1730	81.899	5.239
1	7	20	1800	81.899	5.299
2	7	6	1302	79.000	.659
2	7	6	1332	78.899	.639
2	7	6	1402	78.899	.759
2	7	6	1432	79.000	.939
2	7	6	1502	78.699	.939
2	7	6	1532	78.899	1.119
2	7	6	1602	79.000	1.099
2	7	6	1632	78.899	.879
2	7	6	1702	78.899	1.000
2	7	6	1732	79.099	1.079
2	7	6	1802	78.899	.959
2	7	6	1832	78.899	1.039
2	7	6	1902	78.899	.899
2	7	6	1932	78.899	1.099
2	7	6	2002	78.890	1.220
2	7	6	2032	78.899	1.359
2	7	6	2102	78.899	1.279
2	7	6	2132	79.000	1.339
2	7	6	2202	78.899	1.039
2	7	6	2232	78.899	1.419
2	7	6	2302	78.799	1.139
2	7	6	2332	78.899	1.339
2	7	7	2	78.899	1.139
2	7	7	32	78.899	1.279
2	7	7	102	79.000	1.319
2	7	7	132	79.000	1.419
2	7	7	202	79.000	1.470
2	7	7	232	79.000	1.539
2	7	7	302	79.000	1.619
2	7	7	332	79.000	1.639
2	7	7	402	79.099	.299
2	7	7	432	79.199	.299
2	7	7	502	79.199	.299
2	7	7	532	79.099	.279

Sta.	Mo.	Day	Time	Temp.	D.O.
2	7	7	602	79.000	.299
2	7	7	632	79.000	.279
2	7	7	702	79.099	.379
2	7	7	732	78.899	.379
2	7	7	802	78.899	.439
2	7	7	832	78.899	.439
2	7	7	902	79.000	.399
2	7	7	932	78.899	.500
2	7	7	1002	78.899	.459
2	7	7	1032	78.899	.439
2	7	7	1102	78.899	.459
2	7	7	1132	78.899	.579
2	7	7	1202	78.899	.719
2	7	7	1232	78.899	.639
2	7	7	1302	78.899	.719
2	7	7	1332	78.899	.879
2	7	7	1402	78.899	.939
2	7	7	1432	78.899	.959
2	7	7	1502	78.899	.899
2	7	7	1532	78.899	1.079
2	7	7	1602	78.899	1.219
2	7	7	1632	78.899	1.179
2	7	7	1702	78.899	1.359
2	7	7	1732	78.899	1.139
2	7	7	1802	79.000	1.379
2	7	7	1832	79.199	1.500
2	7	7	1902	79.199	1.519
2	7	7	1932	79.199	1.639
2	7	7	2002	79.199	1.479
2	7	7	2032	79.199	1.500
2	7	7	2102	79.199	1.599
2	7	7	2132	79.299	1.719
2	7	7	2202	79.099	1.359
2	7	7	2232	79.000	1.559
2	7	7	2302	79.099	.719
2	7	7	2332	79.199	1.279
2	7	8	2	79.199	.739
2	7	8	32	79.299	1.019
2	7	8	102	79.299	.839
2	7	8	132	79.399	1.099

Sta.	Mo.	Day	Time	Temp.	D.O.
2	7	8	202	79.199	.899
2	7	8	232	79.299	1.219
2	7	8	302	79.500	1.339
2	7	8	332	79.399	1.299
2	7	8	402	79.399	1.379
2	7	8	432	79.199	1.479
2	7	8	502	79.340	1.540
2	7	8	532	79.500	1.619
2	7	8	602	79.500	1.379
2	7	8	632	79.500	1.599
2	7	8	702	79.500	1.500
2	7	8	732	79.500	1.500
2	7	8	802	79.500	1.639
2	7	8	832	79.500	1.719
2	7	8	902	79.500	1.719
2	7	8	932	79.450	1.690
2	7	8	1002	79.399	1.679
2	7	8	1032	79.299	1.759
2	7	8	1102	79.399	1.799
2	7	8	1132	79.299	1.779
2	7	8	1202	79.199	1.879
2	7	8	1232	79.299	1.939
2	7	8	1302	79.399	2.019
2	7	8	1332	79.399	2.059
2	7	8	1402	79.199	.739
2	7	8	1432	79.299	.959
2	7	8	1502	79.299	.979
2	7	8	1532	79.199	1.059
2	7	8	1602	79.299	1.439
2	7	8	1632	79.399	1.359
2	7	8	1702	79.199	1.619
2	7	8	1732	79.199	1.539
2	7	8	1802	79.199	1.559
2	7	8	1832	79.199	1.719
2	7	8	1902	79.299	1.759
2	7	8	1932	79.500	1.879
2	7	8	2002	79.399	1.839
2	7	8	2032	79.500	1.899
2	7	8	2102	79.500	2.000
2	7	8	2132	79.500	1.939

Sta.	Mo.	Day	Time	Temp.	D.O.
2	7	8	2202	79.500	2.059
2	7	8	2232	79.500	2.139
2	7	8	2302	79.500	2.159
2	7	8	2332	79.500	2.179
2	7	9	2	79.699	2.139
2	7	9	32	79.699	2.279
2	7	9	102	79.699	2.279
2	7	9	132	79.699	2.359
2	7	9	202	79.699	2.399
2	7	9	232	79.699	2.359
2	7	9	302	79.599	2.319
2	7	9	332	79.500	2.299
2	7	9	402	79.500	2.299
2	7	9	432	79.500	2.379
2	7	9	502	79.500	2.399
2	7	9	532	79.699	2.379
2	7	9	602	79.599	2.399
2	7	9	632	79.599	2.399
2	7	9	702	79.500	2.459
2	7	9	732	79.500	2.379
2	7	9	802	79.299	2.399
2	7	9	832	79.399	2.399
2	7	9	902	79.500	2.339
2	7	9	932	79.500	2.379
2	7	9	1002	79.399	2.379
2	7	9	1032	79.199	2.299
2	7	9	1102	79.399	2.359
2	7	9	1132	79.399	2.379
2	7	9	1202	79.099	2.279
2	7	9	1232	79.399	2.299
2	7	9	1302	79.399	2.239
2	7	9	1332	79.450	2.250
2	7	9	1402	79.500	2.299
2	7	9	1432	79.500	2.219
2	7	9	1502	79.500	2.279
2	7	9	1532	79.500	2.199
2	7	9	1602	79.500	2.179
2	7	9	1632	79.500	2.239
2	7	9	1702	79.500	2.159
2	7	9	1732	79.500	2.259

Sta.	Mo.	Day	Time	Temp.	D.O.
2	7	9	1802	79.500	2.239
2	7	9	1832	79.699	2.139
2	7	9	1902	79.699	2.199
2	7	9	1932	79.899	2.359
2	7	9	2002	79.799	2.199
2	7	9	2032	79.699	2.399
2	7	9	2102	80.000	2.399
2	7	9	2132	80.000	.319
2	7	9	2202	79.899	.519
2	7	9	2232	80.000	.359
2	7	9	2302	80.000	.299
2	7	9	2332	80.199	.279
2	7	10	2	80.199	.259
2	7	10	32	80.299	.279
2	7	10	102	80.299	.239
2	7	10	132	80.299	.299
2	7	10	202	80.500	.299
2	7	10	232	80.299	.299
2	7	10	302	80.500	.299
2	7	10	332	80.699	.339
2	7	10	402	80.399	.319
2	7	10	432	80.699	.399
2	7	10	502	80.500	.439
2	7	10	532	80.699	.399
2	7	10	602	80.599	.439
2	7	10	632	80.699	.399
2	7	10	702	80.799	.419
2	7	10	732	80.899	.579
2	7	10	802	80.799	.559
2	7	10	832	80.899	.819
2	7	10	902	80.799	.959
2	7	10	932	80.799	1.139
2	7	10	1002	80.899	.759
2	7	10	1032	80.799	.799
2	7	10	1102	80.840	1.070
2	7	10	1132	80.899	1.359
2	7	10	1202	80.899	.879
2	7	10	1232	81.000	1.159
2	7	10	1302	80.899	1.099
2	7	10	1332	81.000	1.059

Sta.	Mo.	Day	Time	Temp.	D.O.
2	7	10	1402	80.899	1.099
2	7	10	1432	80.990	1.120
2	7	10	1502	81.099	1.159
2	7	10	1532	81.299	1.379
2	7	10	1602	81.099	1.139
2	7	10	1632	81.230	1.180
2	7	10	1702	81.370	1.230
2	7	10	1732	81.500	1.299
2	7	10	1802	81.599	1.919
2	7	10	1832	81.599	1.779
2	7	10	1902	81.699	1.779
2	7	10	1932	81.699	1.739
2	7	10	2002	81.790	1.620
2	7	10	2032	81.899	1.519
2	7	10	2102	81.699	1.500
2	7	10	2132	81.899	1.819
2	7	10	2202	82.000	1.479
2	7	10	2232	82.000	1.799
2	7	10	2302	82.000	1.959
2	7	10	2332	82.099	1.639
2	7	11	2	82.199	1.699
2	7	11	32	82.199	1.939
2	7	11	102	82.299	2.039
2	7	11	132	82.199	1.879
2	7	11	202	82.099	2.059
2	7	11	232	82.299	1.839
2	7	11	302	82.399	1.739
2	7	11	332	82.500	1.959
2	7	11	402	82.599	1.919
2	7	11	432	82.699	1.939
2	7	11	502	82.699	2.039
2	7	11	532	82.799	2.000
2	7	11	602	82.899	2.079
2	7	11	632	82.699	2.279
2	7	11	702	82.899	2.319
2	7	11	732	82.799	2.299
2	7	11	802	82.810	2.310
2	7	11	832	82.830	2.330
2	7	11	902	82.850	2.350
2	7	11	932	82.870	2.370

Sta.	Mo.	Day	Time	Temp.	D.O.
2	7	11	1002	82.899	2.399
2	7	11	1032	83.000	.679
2	7	11	1102	83.090	.940
2	7	11	1132	83.199	1.219
2	7	11	1202	83.099	1.319
2	7	11	1232	83.199	1.500
2	7	11	1302	83.199	1.219
2	7	11	1332	83.399	1.379
2	7	11	1402	83.299	1.259
2	7	11	1432	83.299	1.419
2	7	11	1502	83.299	1.339
2	7	11	1532	83.500	1.000
2	7	11	1602	83.199	1.339
2	7	11	1632	83.299	1.099
2	7	11	1702	83.199	1.179
2	7	11	1732	83.500	1.539
2	7	11	1802	83.500	1.319
2	7	11	1832	83.699	1.539
2	7	11	1902	83.699	1.399
2	7	11	1932	83.699	1.539
2	7	11	2002	83.799	1.719
2	7	11	2032	83.699	1.539
2	7	11	2102	83.699	1.599
2	7	11	2132	83.799	1.839
2	7	11	2202	83.799	1.759
2	7	11	2232	83.799	1.879
2	7	11	2302	83.699	1.979
2	7	11	2332	83.799	2.000
2	7	12	2	83.599	2.119
2	7	12	32	83.599	2.259
2	7	12	102	83.899	2.239
2	7	12	132	83.899	2.299
2	7	12	202	83.599	2.279
2	7	12	232	83.799	2.279
2	7	12	302	83.699	2.279
2	7	12	332	83.699	2.339
2	7	12	402	83.500	2.359
2	7	12	432	83.399	2.359
2	7	12	502	83.500	2.459
2	7	12	532	83.699	2.500

Sta.	Mo.	Day	Time	Temp.	D.O.
2	7	12	602	83.699	2.439
2	7	12	632	83.500	2.479
2	7	12	702	83.399	2.459
2	7	12	732	83.500	2.479
2	7	12	802	83.399	2.500
2	7	12	832	83.299	2.459
2	7	12	902	83.299	2.539
2	7	12	932	83.199	2.579
2	7	12	1002	83.199	2.519
2	7	12	1032	83.099	2.679
2	7	12	1102	82.990	2.690
2	7	12	1132	82.899	2.719
2	7	12	1202	83.099	2.639
2	7	12	1232	83.099	2.819
2	7	12	1302	83.000	2.839
2	7	12	1332	83.099	2.959
2	7	12	1402	83.299	2.959
2	7	12	1432	83.260	2.910
2	7	12	1502	83.220	2.870
2	7	12	1532	83.199	2.839
2	7	12	1602	83.270	2.860
2	7	12	1632	83.350	2.880
2	7	12	1702	83.430	2.900
2	7	12	1732	83.500	2.939
2	7	12	1802	83.599	2.859
2	7	12	1832	83.500	2.919
2	7	12	1902	83.500	3.019
2	7	12	1932	83.550	3.020
2	7	12	2002	83.599	3.039
2	7	12	2032	83.199	2.959
2	7	12	2102	83.500	3.039
2	7	12	2132	83.500	3.059
2	7	12	2202	83.500	3.059
2	7	12	2232	83.500	3.070
2	7	12	2302	83.500	3.099
2	7	12	2332	83.500	3.139
2	7	13	2	83.600	2.110
2	7	13	32	83.699	1.099
2	7	13	102	83.660	1.290
2	7	13	132	83.620	1.490

Sta.	Mo.	Day	Time	Temp.	D.O.
2	7	13	202	83.599	1.699
2	7	13	232	83.699	1.719
2	7	13	302	83.599	1.879
2	7	13	332	83.699	1.939
2	7	13	402	83.699	1.779
2	7	13	432	83.799	1.779
2	7	13	502	83.699	1.879
2	7	13	532	83.799	1.819
2	7	13	602	83.740	1.850
2	7	13	632	83.699	1.899
2	7	13	702	83.799	1.859
2	7	13	732	83.899	2.019
2	7	13	802	84.000	2.099
2	7	13	832	83.899	2.239
2	7	13	902	83.890	2.250
2	7	13	932	83.899	2.279
2	7	13	1002	83.840	2.300
2	7	13	1032	83.790	2.340
2	7	13	1102	83.740	2.380
2	7	13	1132	83.699	2.419
2	7	13	1202	83.699	2.539
2	7	13	1232	83.690	2.570
2	7	13	1302	83.690	2.610
2	7	13	1332	83.699	2.659
2	7	13	1402	83.699	2.639
2	7	13	1432	83.590	2.690
2	7	13	1502	83.500	2.759
2	7	13	1532	83.500	2.759
2	7	13	1602	83.400	2.810
2	7	13	1632	83.399	2.879
2	7	13	1702	83.599	2.979
2	7	13	1732	83.299	3.039
2	7	13	1802	83.599	3.139
2	7	13	1832	83.500	3.039
2	7	13	1902	83.399	3.139
2	7	13	1932	83.399	3.179
2	7	13	2002	83.500	3.019
2	7	13	2032	83.399	3.179
2	7	13	2102	83.390	3.260
2	7	13	2132	83.399	3.359

Sta.	Mo.	Day	Time	Temp.	D.O.
2	7	13	2202	83.500	3.379
2	7	13	2232	83.599	3.359
2	7	13	2302	83.500	3.379
2	7	13	2332	83.699	3.379
2	7	14	2	83.500	3.559
2	7	14	32	83.399	3.539
2	7	14	102	83.599	3.500
2	7	14	132	83.599	3.500
2	7	14	202	83.440	3.460
2	7	14	232	83.299	3.419
2	7	14	302	83.299	3.479
2	7	14	332	83.399	3.500
2	7	14	402	83.399	3.479
2	7	14	432	83.290	3.490
2	7	14	502	83.199	3.500
2	7	14	532	83.000	3.459
2	7	14	602	83.299	3.539
2	7	14	632	83.000	3.500
2	7	14	702	83.299	4.519
2	7	14	732	83.000	3.699
2	7	14	802	83.000	3.699
2	7	14	832	82.950	3.710
2	7	14	902	82.899	3.739
2	7	14	932	82.699	3.819
2	7	14	1002	82.799	3.819
2	7	14	1032	82.699	3.819
2	7	14	1102	82.799	3.799
2	7	14	1132	82.760	3.820
2	7	14	1202	82.720	3.840
2	7	14	1232	82.699	3.879
2	7	14	1302	83.640	3.870
2	7	14	1332	82.599	3.879
2	7	14	1402	82.500	3.899
2	7	14	1432	82.500	3.920
2	7	14	1502	82.500	3.959
2	7	14	1532	82.500	4.039
2	7	14	1602	82.450	4.060
2	7	14	1632	82.399	4.099
2	7	14	1702	82.390	4.070
2	7	14	1732	82.390	4.050

Sta.	Mo.	Day	Time	Temp.	D.O.
2	7	14	1802	82.390	4.020
2	7	14	1832	82.399	4.000
2	7	14	1902	82.199	3.979
2	7	14	1932	82.199	4.079
2	7	14	2002	82.190	4.030
2	7	14	2032	82.199	4.000
2	7	14	2102	82.199	4.000
2	7	14	2132	82.299	4.079
2	7	14	2202	82.199	4.179
2	7	14	2232	82.099	4.099
2	7	14	2302	82.099	4.039
2	7	14	2332	82.199	4.039
2	7	15	2	81.799	3.679
2	7	15	32	82.099	2.239
2	7	15	102	82.199	2.879
2	7	15	132	82.199	2.899
2	7	15	202	82.199	2.779
2	7	15	232	82.099	3.039
2	7	15	302	82.000	2.979
2	7	15	332	82.040	2.960
2	7	15	402	82.099	2.959
2	7	15	432	82.199	3.079
2	7	15	502	82.000	3.199
2	7	15	532	82.000	3.379
2	7	15	602	82.000	3.379
2	7	15	632	82.000	3.459
2	7	15	702	81.799	3.479
2	7	15	732	81.599	3.359
2	7	15	802	81.500	3.439
2	7	15	832	81.599	3.319
2	7	15	902	81.500	3.379
2	7	15	932	81.599	3.339
2	7	15	1002	81.510	3.330
2	7	15	1032	81.440	3.330
2	7	15	1102	81.370	3.330
2	7	15	1132	81.299	3.339
2	7	15	1202	80.899	3.399
2	7	15	1232	80.899	3.500
2	7	15	1302	80.890	3.550
2	7	15	1332	80.899	3.619

Sta.	Mo.	Day	Time	Temp.	D.O.
2	7	15	1402	80.820	3.600
2	7	15	1432	80.760	3.600
2	7	15	1502	80.699	3.599
2	7	15	1532	80.500	3.579
2	7	15	1602	80.399	3.599
2	7	15	1632	80.299	3.679
2	7	15	1702	80.199	3.639
2	7	15	1732	80.199	3.679
2	7	15	1802	80.000	3.639
2	7	15	1832	80.060	3.760
2	7	15	1902	80.130	3.900
2	7	15	1932	80.199	4.039
2	7	15	2002	80.199	4.159
2	7	15	2032	80.099	4.119
2	7	15	2102	80.000	4.279
2	7	15	2132	80.199	4.379
2	7	15	2202	80.000	4.459
2	7	15	2232	80.199	4.579
2	7	15	2302	80.000	4.599
2	7	15	2332	80.000	4.599
2	7	16	2	80.099	4.639
2	7	16	32	80.140	4.580
2	7	16	102	80.199	4.539
2	7	16	132	80.299	4.679
2	7	16	202	80.000	4.599
2	7	16	232	80.199	4.639
2	7	16	302	80.299	4.739
2	7	16	332	80.199	4.779
2	7	16	402	80.000	4.839
2	7	16	432	80.199	4.859
2	7	16	502	80.299	4.939
2	7	16	532	80.099	4.939
2	7	16	602	80.199	4.919
2	7	16	632	80.199	4.879
2	7	16	702	80.199	4.859
2	7	16	732	80.199	4.919
2	7	16	802	80.099	4.979
2	7	16	832	80.099	4.939
2	7	16	902	80.099	4.899
2	7	16	932	79.899	3.219

Sta.	Mo.	Day	Time	Temp.	D.O.
2	7	16	1002	79.899	4.399
2	7	16	1032	79.699	4.079
2	7	16	1102	79.699	4.000
2	7	16	1132	79.799	4.179
2	7	16	1202	79.699	4.159
2	7	16	1232	79.699	4.259
2	7	16	1302	79.699	4.299
2	7	16	1332	79.699	4.319
2	7	16	1402	79.799	4.399
2	7	16	1432	79.500	4.519
2	7	16	1502	79.500	4.599
2	7	16	1532	79.599	4.699
2	7	16	1602	79.599	4.719
2	7	16	1632	79.599	4.939
2	7	16	1702	79.699	4.919
2	7	16	1732	79.500	4.939
2	7	16	1802	79.500	5.019
2	7	16	1832	79.500	5.059
2	7	16	1902	79.500	5.179
2	7	16	1932	79.500	5.139
2	7	16	2002	79.399	5.179
2	7	16	2032	79.500	5.239
2	7	16	2102	79.399	5.139
2	7	16	2132	79.500	5.239
2	7	16	2202	79.599	5.239
2	7	16	2232	79.500	5.179
2	7	16	2302	79.600	5.260
2	7	16	2332	79.699	5.359
2	7	17	2	79.599	5.299
2	7	17	32	79.599	5.359
2	7	17	102	79.399	5.399
2	7	17	132	79.599	5.339
2	7	17	202	79.500	5.339
2	7	17	232	79.699	5.279
2	7	17	302	79.799	5.339
2	7	17	332	79.699	5.299
2	7	17	402	79.699	5.279
2	7	17	432	79.699	5.279
2	7	17	502	79.699	5.359
2	7	17	532	79.500	5.339

Sta.	Mo.	Day	Time	Temp.	D.O.
2	7	17	602	79.600	3.360
2	7	17	632	79.699	5.399
2	7	17	702	79.599	5.439
2	7	17	732	79.399	5.359
2	7	17	802	79.500	5.379
2	7	17	832	79.500	5.330
2	7	17	902	79.500	5.299
2	7	17	932	79.399	5.399
2	7	17	1002	79.299	5.359
2	7	17	1032	79.399	5.359
2	7	17	1102	79.399	5.299
2	7	17	1132	79.299	5.279
2	7	17	1202	79.390	5.290
2	7	17	1232	79.490	5.320
2	7	17	1302	79.590	5.350
2	7	17	1332	79.699	5.379
2	7	17	1402	79.500	5.339
2	7	17	1432	79.699	5.500
2	7	17	1502	79.399	5.439
2	7	17	1532	79.500	5.419
2	7	17	1602	79.500	5.439
2	7	17	1632	79.500	5.439
2	7	17	1702	79.560	5.410
2	7	17	1732	79.630	5.390
2	7	17	1802	79.699	5.379
2	7	17	1832	79.699	5.399
2	7	17	1902	79.699	5.339
2	7	17	1932	79.799	5.339
2	7	17	2002	79.699	5.239
2	7	17	2032	79.899	5.279
2	7	17	2102	79.699	5.339
2	7	17	2132	79.699	5.379
2	7	17	2202	79.699	5.379
2	7	17	2232	79.699	5.399
2	7	17	2302	79.599	5.419
2	7	17	2332	79.699	5.379
2	7	18	2	79.699	5.439
2	7	18	32	79.699	5.379
2	7	18	102	80.000	5.459
2	7	18	132	79.799	5.479

Sta.	Mo.	Day	Time	Temp.	D.O.
2	7	18	202	79.799	5.399
2	7	18	232	79.799	5.359
2	7	18	302	79.799	5.339
2	7	18	332	79.699	5.339
2	7	18	402	79.799	5.279
2	7	18	432	79.699	5.259
2	7	18	502	79.899	5.299
2	7	18	532	79.799	5.339
2	7	18	602	79.740	5.330
2	7	18	632	79.699	5.339
2	7	18	702	79.799	5.359
2	7	18	732	79.799	5.299
2	7	18	802	79.799	5.279
2	7	18	832	79.699	5.839
2	7	18	902	79.500	3.199
2	7	18	932	79.699	3.399
2	7	18	1002	79.699	3.779
2	7	18	1032	79.799	3.679
2	7	18	1102	79.699	3.639
2	7	18	1132	79.690	3.660
2	7	18	1202	79.699	3.699
2	7	18	1232	79.640	3.740
2	7	18	1302	79.599	3.799
2	7	18	1332	79.699	3.939
2	7	18	1402	79.599	4.019
2	7	18	1432	79.699	4.079
2	7	18	1502	79.699	4.199
2	7	18	1539	79.699	4.159
2	7	18	1602	79.699	4.159
2	7	18	1632	79.699	4.199
2	7	18	1702	79.699	4.179
2	7	18	1732	79.599	4.199
2	7	18	1802	79.599	4.279
2	7	18	1832	79.699	4.339
2	7	18	1902	79.699	4.379
2	7	18	1932	79.500	4.419
2	7	18	2002	79.500	4.459
2	7	18	2032	79.899	4.599
2	7	18	2102	79.799	4.579
2	7	18	2132	79.899	5.779

Sta.	Mo.	Day	Time	Temp.	D.O.
2	7	18	2202	79.699	4.939
2	7	18	2232	79.699	4.939
2	7	18	2302	79.799	4.839
2	7	18	2332	79.799	4.679
2	7	19	2	79.899	4.719
2	7	19	32	80.000	4.599
2	7	19	102	79.799	4.679
2	7	19	132	80.000	4.639
2	7	19	202	79.799	4.599
2	7	19	232	80.000	4.619
2	7	19	302	80.000	4.559
2	7	19	332	79.799	4.579
2	7	19	402	79.899	4.599
2	7	19	432	80.000	4.539
2	7	19	502	79.899	4.439
2	7	19	532	79.950	4.410
2	7	19	602	80.000	4.399
2	7	19	632	79.899	4.399
2	7	19	702	79.699	4.339
2	7	19	732	80.000	4.279
2	7	19	802	80.000	4.279
2	7	19	832	80.000	4.239
2	7	19	902	80.199	4.219
2	7	19	932	80.099	4.179
2	7	19	1002	80.050	4.130
2	7	19	1032	80.000	4.099
2	7	19	1102	80.199	4.039
2	7	19	1132	80.199	4.039
2	7	19	1202	80.099	4.000
2	7	19	1232	80.000	3.939
2	7	19	1302	80.199	3.939
2	7	19	1332	80.299	3.939
2	7	19	1402	80.199	3.899
2	7	19	1432	80.299	3.879
2	7	19	1502	80.199	3.879
2	7	19	1532	80.299	3.819
2	7	19	1602	80.199	3.799
2	7	19	1632	80.299	3.759
2	7	19	1702	80.099	3.739
2	7	19	1732	80.299	3.699

Sta.	Mo.	Day	Time	Temp.	D.C.
2	7	19	1802	80.399	3.639
2	7	19	1832	80.399	3.659
2	7	19	1902	80.500	3.579
2	7	19	1932	80.399	3.619
2	7	19	2002	80.500	3.559
2	7	19	2032	80.299	3.519
2	7	19	2102	80.299	3.500
2	7	19	2132	80.599	3.500
2	7	19	2202	80.599	3.459
2	7	19	2232	80.699	3.399
2	7	19	2302	80.699	3.399
2	7	19	2332	80.500	3.359
2	7	20	2	80.699	3.339
2	7	20	32	80.699	3.299
2	7	20	102	80.599	3.279
2	7	20	132	80.599	3.279
2	7	20	202	80.699	3.279
2	7	20	232	80.500	3.239
2	7	20	302	80.699	3.179
2	7	20	332	80.699	3.139
2	7	20	402	80.799	3.139
2	7	20	432	80.799	3.139
2	7	20	502	80.899	3.119
2	7	20	532	80.890	3.100
2	7	20	602	80.899	3.099
2	7	20	632	80.899	3.079
2	7	20	702	80.899	3.039
2	7	20	732	80.799	3.759
2	7	20	802	80.840	3.410
2	7	20	832	80.899	3.079
2	7	20	902	80.899	2.979
2	7	20	932	80.799	2.939
2	7	20	1002	80.899	2.879
2	7	20	1032	80.699	2.859
2	7	20	1102	80.799	2.500
2	7	20	1132	80.899	2.719
2	7	20	1202	80.899	2.639
2	7	20	1232	80.799	2.679
2	7	20	1302	81.000	2.659
2	7	20	1332	80.950	2.660

Sta.	Mo.	Day	Time	Temp.	D.O.
2	7	20	1402	80.899	2.679
2	7	20	1432	80.890	2.650
2	7	20	1502	80.899	2.639
2	7	20	1532	80.899	2.639
2	7	20	1602	80.890	2.590
2	7	20	1632	80.899	2.559
2	7	20	1702	80.950	2.550
2	7	20	1732	81.000	2.559
2	7	20	1802	81.199	2.559
3	7	6	1304	79.299	1.159
3	7	6	1334	79.500	1.059
3	7	6	1404	79.399	1.199
3	7	6	1434	79.199	1.039
3	7	6	1504	79.000	.759
3	7	6	1534	79.500	1.139
3	7	6	1604	79.500	1.500
3	7	6	1634	79.799	2.379
3	7	6	1704	79.799	1.639
3	7	6	1734	79.799	1.500
3	7	6	1804	79.699	1.019
3	7	6	1834	79.799	.899
3	7	6	1904	79.699	.959
3	7	6	1934	79.699	.859
3	7	6	2004	79.500	.959
3	7	6	2034	79.399	.819
3	7	6	2104	79.599	1.000
3	7	6	2134	79.299	1.159
3	7	6	2204	79.299	1.159
3	7	6	2234	79.299	1.099
3	7	6	2304	79.199	1.000
3	7	6	2334	79.199	.879
3	7	7	4	79.199	1.139
3	7	7	34	79.199	.779
3	7	7	104	79.000	.739
3	7	7	134	78.899	.739
3	7	7	204	78.799	.699
3	7	7	234	79.000	.639
3	7	7	304	78.799	.659
3	7	7	334	78.899	.659
3	7	7	404	78.899	.639

Sta.	Mo.	Day	Time	Temp.	D.O.
3	7	7	434	78.899	.559
3	7	7	504	78.899	.459
3	7	7	534	79.000	.439
3	7	7	604	78.899	.419
3	7	7	634	79.199	.399
3	7	7	704	79.199	.379
3	7	7	734	79.099	.439
3	7	7	804	79.199	.379
3	7	7	834	78.899	.439
3	7	7	904	79.000	.399
3	7	7	934	79.099	.319
3	7	7	1004	79.199	.519
3	7	7	1034	79.299	.859
3	7	7	1104	79.399	.699
3	7	7	1134	79.199	.759
3	7	7	1204	79.099	.719
3	7	7	1234	79.199	.839
3	7	7	1304	79.199	.699
3	7	7	1334	79.399	1.279
3	7	7	1404	79.500	1.159
3	7	7	1434	79.500	1.579
3	7	7	1504	79.199	1.139
3	7	7	1534	79.500	1.319
3	7	7	1604	79.599	1.459
3	7	7	1634	79.699	1.739
3	7	7	1704	79.699	1.519
3	7	7	1734	79.799	1.079
3	7	7	1804	79.599	.759
3	7	7	1834	79.500	.799
3	7	7	1904	79.500	.639
3	7	7	1934	79.599	.579
3	7	7	2004	79.500	.579
3	7	7	2034	79.699	.599
3	7	7	2104	79.699	.699
3	7	7	2134	79.500	.619
3	7	7	2204	79.500	.879
3	7	7	2234	79.500	.879
3	7	7	2304	79.199	.659
3	7	7	2334	79.199	.819
3	7	8	4	79.000	.739

Sta.	Mo.	Day	Time	Temp.	D.O.
3	7	8	34	79.199	.819
3	7	8	104	78.899	.699
3	7	8	134	79.000	.819
3	7	8	204	79.099	.659
3	7	8	234	78.899	.679
3	7	8	304	78.699	.599
3	7	8	334	78.899	.579
3	7	8	404	78.899	.579
3	7	8	434	78.699	.519
3	7	8	504	78.799	.479
3	7	8	534	78.899	.359
3	7	8	604	78.899	.359
3	7	8	634	78.899	.299
3	7	8	704	78.799	.299
3	7	8	734	78.799	.299
3	7	8	804	78.799	.299
3	7	8	834	78.899	.259
3	7	8	904	78.899	.259
3	7	8	934	78.699	.359
3	7	8	1004	78.899	.259
3	7	8	1034	78.899	.379
3	7	8	1104	78.699	.539
3	7	8	1134	78.699	.559
3	7	8	1204	78.799	.419
3	7	8	1234	78.899	.539
3	7	8	1304	78.699	.539
3	7	8	1334	78.799	.519
3	7	8	1404	78.899	.539
3	7	8	1434	78.899	.500
3	7	8	1504	78.799	.459
3	7	8	1534	78.899	.699
3	7	8	1604	78.699	.559
3	7	8	1634	78.899	.419
3	7	8	1704	78.699	.439
3	7	8	1734	78.799	.579
3	7	8	1804	79.099	.739
3	7	8	1834	79.000	.679
3	7	8	1904	79.000	.819
3	7	8	1934	78.899	.419
3	7	8	2004	78.899	.339

Sta.	Mo.	Day	Time	Temp.	D.O.
3	7	8	2034	78.899	.439
3	7	8	2104	78.899	.539
3	7	8	2134	78.899	.439
3	7	8	2204	78.899	.419
3	7	8	2234	78.799	.359
3	7	8	2304	78.799	.299
3	7	8	2334	78.799	.379
3	7	9	4	78.699	.359
3	7	9	34	78.899	.359
3	7	9	104	78.799	.339
3	7	9	134	78.799	.319
3	7	9	204	78.699	.359
3	7	9	234	78.799	.299
3	7	9	304	78.899	.319
3	7	9	334	78.699	.419
3	7	9	404	78.799	.339
3	7	9	434	78.699	.339
3	7	9	504	78.699	.299
3	7	9	534	78.799	.239
3	7	9	604	78.699	.279
3	7	9	634	78.699	.199
3	7	9	704	78.599	.179
3	7	9	734	78.699	.199
3	7	9	804	78.599	.159
3	7	9	834	78.699	.179
3	7	9	904	78.699	.179
3	7	9	934	78.699	.179
3	7	9	1004	78.699	.199
3	7	9	1034	78.799	.179
3	7	9	1104	78.899	.259
3	7	9	1134	79.000	.379
3	7	9	1204	79.099	.379
3	7	9	1234	79.399	.459
3	7	9	1304	79.599	.679
3	7	9	1334	79.690	.670
3	7	9	1404	79.799	.679
3	7	9	1434	80.000	.559
3	7	9	1504	80.199	.559
3	7	9	1534	80.500	1.059
3	7	9	1604	80.399	.979

Sta.	Mo.	Day	Time	Temp.	D.O.
3	7	9	1634	80.899	5.639
3	7	9	1704	80.399	2.879
3	7	9	1734	80.500	1.799
3	7	9	1804	80.299	1.099
3	7	9	1834	80.399	2.019
3	7	9	1904	79.899	.739
3	7	9	1934	79.799	.579
3	7	9	2004	79.500	.359
3	7	9	2034	79.500	.279
3	7	9	2104	79.599	.279
3	7	9	2134	79.599	.259
3	7	9	2204	80.000	.979
3	7	9	2234	79.899	.439
3	7	9	2304	79.699	.399
3	7	9	2334	79.899	.559
3	7	10	4	79.599	.359
3	7	10	34	79.599	.359
3	7	10	104	79.699	.359
3	7	10	134	79.599	.339
3	7	10	204	79.699	.299
3	7	10	234	79.899	.299
3	7	10	304	79.699	.299
3	7	10	334	79.899	.379
3	7	10	404	80.099	1.159
3	7	10	434	79.500	.379
3	7	10	504	79.799	.279
3	7	10	534	79.799	.439
3	7	10	604	79.699	.239
3	7	10	634	79.599	.259
3	7	10	704	79.500	.259
3	7	10	734	79.699	.259
3	7	10	804	79.699	.239
3	7	10	834	79.500	.219
3	7	10	904	79.699	.179
3	7	10	934	79.899	.279
3	7	10	1004	80.000	.199
3	7	10	1034	80.399	.599
3	7	10	1104	80.199	.319
3	7	10	1134	80.500	.459
3	7	10	1204	80.799	.799

Sta.	Mo.	Day	Time	Temp.	D.O.
3	7	10	1234	80.599	.439
3	7	10	1304	81.899	1.779
3	7	10	1334	80.699	.639
3	7	10	1404	81.699	1.139
3	7	10	1434	81.699	1.079
3	7	10	1504	83.299	2.919
3	7	10	1534	82.799	5.539
3	7	10	1604	82.399	3.000
3	7	10	1634	82.399	4.039
3	7	10	1704	82.699	3.299
3	7	10	1734	82.000	.979
3	7	10	1804	82.399	2.839
3	7	10	1834	82.000	1.719
3	7	10	1904	81.799	1.659
3	7	10	1934	81.599	.979
3	7	10	2004	81.199	.479
3	7	10	2034	81.299	.619
3	7	10	2104	81.000	.619
3	7	10	2134	80.899	.779
3	7	10	2204	81.000	.579
3	7	10	2234	80.899	.399
3	7	10	2304	81.599	1.739
3	7	10	2334	81.000	.739
3	7	11	4	80.899	.399
3	7	11	34	81.000	.319
3	7	11	104	80.899	.379
3	7	11	134	81.199	.359
3	7	11	204	81.199	.299
3	7	11	234	81.199	.279
3	7	11	304	81.199	.259
3	7	11	334	81.199	.259
3	7	11	404	80.899	.279
3	7	11	434	81.299	1.759
3	7	11	504	81.199	.659
3	7	11	534	81.199	.299
3	7	11	604	81.199	.279
3	7	11	634	81.099	.259
3	7	11	704	81.099	.199
3	7	11	734	80.899	.179
3	7	11	804	80.899	.199

Sta.	Mo.	Day	Time	Temp.	D.O.
3	7	11	834	80.890	.180
3	7	11	904	80.899	.179
3	7	11	934	80.899	.199
3	7	11	1004	81.299	.299
3	7	11	1034	81.299	.339
3	7	11	1104	81.099	.759
3	7	11	1134	81.299	.579
3	7	11	1204	81.500	.639
3	7	11	1234	81.699	.399
3	7	11	1304	82.199	1.019
3	7	11	1334	82.199	1.519
3	7	11	1404	82.099	1.439
3	7	11	1434	81.799	.359
3	7	11	1504	82.000	.359
3	7	11	1534	82.099	.619
3	7	11	1604	82.399	.579
3	7	11	1634	82.500	.679
3	7	11	1704	82.500	.799
3	7	11	1734	82.399	.439
3	7	11	1804	81.899	.299
3	7	11	1834	82.399	1.819
3	7	11	1904	82.399	1.299
3	7	11	1934	82.299	.779
3	7	11	2004	82.099	.639
3	7	11	2034	82.000	.379
3	7	11	2104	81.699	.299
3	7	11	2134	81.899	.459
3	7	11	2204	81.500	.439
3	7	11	2234	81.599	.399
3	7	11	2304	81.699	.319
3	7	11	2334	81.500	.279
3	7	12	4	81.899	.759
3	7	12	34	81.699	.259
3	7	12	104	81.699	.299
3	7	12	134	81.899	.279
3	7	12	204	81.699	.239
3	7	12	234	81.799	.259
3	7	12	304	81.699	.239
3	7	12	334	81.699	.259
3	7	12	404	81.899	.219

Sta.	No.	Day	Time	Temp.	D.O.
3	7	12	434	81.799	.159
3	7	12	504	81.799	.179
3	7	12	534	81.699	.199
3	7	12	604	81.899	.239
3	7	12	634	81.799	.259
3	7	12	704	81.899	.239
3	7	12	734	81.890	.240
3	7	12	804	81.899	.259
3	7	12	834	81.890	.240
3	7	12	904	81.899	.239
3	7	12	934	81.699	.239
3	7	12	1004	82.000	.439
3	7	12	1034	82.199	.619
3	7	12	1104	82.000	.239
3	7	12	1134	81.500	1.419
3	7	12	1204	82.500	3.759
3	7	12	1234	82.399	3.539
3	7	12	1304	82.799	3.739
3	7	12	1334	83.500	4.839
3	7	12	1404	83.500	4.000
3	7	12	1434	83.299	3.959
3	7	12	1504	83.500	3.859
3	7	12	1534	82.799	3.039
3	7	12	1604	83.199	3.039
3	7	12	1634	83.199	3.179
3	7	12	1704	83.199	3.099
3	7	12	1734	84.899	9.699
3	7	12	1804	83.699	4.919
3	7	12	1834	83.590	4.810
3	7	12	1904	83.500	4.719
3	7	12	1934	83.299	2.879
3	7	12	2004	83.199	3.099
3	7	12	2034	82.799	2.759
3	7	12	2104	82.740	2.570
3	7	12	2134	82.699	2.399
3	7	12	2204	82.599	2.379
3	7	12	2234	82.500	2.500
3	7	12	2304	82.500	2.239
3	7	12	2334	82.599	2.259
3	7	13	4	82.299	1.879

Sta.	Mo.	Day	Time	Temp.	D.O.
3	7	13	34	82.500	1.899
3	7	13	104	82.500	2.339
3	7	13	134	82.399	2.019
3	7	13	204	82.500	2.000
3	7	13	234	82.500	2.379
3	7	13	304	82.599	2.000
3	7	13	334	82.599	1.839
3	7	13	404	82.399	1.799
3	7	13	434	82.500	1.839
3	7	13	504	82.399	1.579
3	7	13	534	82.500	1.699
3	7	13	604	82.599	1.539
3	7	13	634	82.599	1.559
3	7	13	704	82.500	1.500
3	7	13	734	82.399	1.639
3	7	13	804	82.299	1.439
3	7	13	834	82.400	1.510
3	7	13	904	82.500	1.599
3	7	13	934	82.699	1.599
3	7	13	1004	82.620	1.570
3	7	13	1034	82.540	1.560
3	7	13	1104	82.470	1.550
3	7	13	1134	82.399	1.539
3	7	13	1204	82.699	1.419
3	7	13	1234	82.599	1.619
3	7	13	1304	82.640	1.740
3	7	13	1334	82.699	1.359
3	7	13	1404	82.699	1.839
3	7	13	1434	82.890	2.120
3	7	13	1504	83.000	2.419
3	7	13	1534	82.899	2.559
3	7	13	1604	83.000	2.739
3	7	13	1634	83.000	2.359
3	7	13	1704	82.899	1.979
3	7	13	1734	82.899	1.899
3	7	13	1804	82.899	1.839
3	7	13	1834	83.500	4.399
3	7	13	1904	83.500	5.899
3	7	13	1934	82.899	4.239
3	7	13	2004	83.199	2.119

Sta.	Mo.	Day	Time	Temp.	D.O.
3	7	13	2034	82.899	1.859
3	7	13	2104	82.760	1.790
3	7	13	2134	82.630	1.720
3	7	13	2204	82.500	1.659
3	7	13	2234	82.699	1.500
3	7	13	2304	82.699	1.919
3	7	13	2334	82.399	1.379
3	7	14	4	82.299	1.279
3	7	14	34	82.500	1.159
3	7	14	104	82.500	1.179
3	7	14	134	82.500	1.119
3	7	14	204	82.299	1.219
3	7	14	234	82.399	1.539
3	7	14	304	82.500	1.139
3	7	14	334	82.500	1.199
3	7	14	404	82.000	1.279
3	7	14	434	82.299	1.199
3	7	14	504	82.199	1.299
3	7	14	534	82.000	1.279
3	7	14	604	82.099	1.339
3	7	14	634	81.899	1.319
3	7	14	704	82.000	1.339
3	7	14	734	82.199	1.279
3	7	14	804	82.140	1.290
3	7	14	834	82.099	1.319
3	7	14	904	82.000	1.179
3	7	14	934	82.099	1.559
3	7	14	1004	82.299	1.179
3	7	14	1034	82.399	1.459
3	7	14	1104	82.399	1.339
3	7	14	1134	82.699	1.879
3	7	14	1204	82.599	1.379
3	7	14	1234	82.699	1.479
3	7	14	1304	82.500	1.099
3	7	14	1334	82.500	.919
3	7	14	1404	82.199	1.000
3	7	14	1434	82.290	1.120
3	7	14	1504	82.399	1.259
3	7	14	1534	82.290	1.290
3	7	14	1604	82.199	1.339

Sta.	Mo.	Day	Time	Temp.	D.O.
3	7	14	1634	82.199	1.419
3	7	14	1704	82.150	1.430
3	7	14	1734	82.120	1.450
3	7	14	1804	82.099	1.479
3	7	14	1834	82.199	1.599
3	7	14	1904	82.099	1.559
3	7	14	1934	82.000	1.619
3	7	14	2004	82.099	1.919
3	7	14	2034	82.299	2.059
3	7	14	2104	82.000	1.599
3	7	14	2134	82.000	1.379
3	7	14	2204	81.899	1.439
3	7	14	2234	81.899	1.179
3	7	14	2304	82.000	1.139
3	7	14	2334	82.000	.979
3	7	15	4	82.000	.879
3	7	15	34	81.899	.739
3	7	15	104	81.799	.699
3	7	15	134	81.899	.839
3	7	15	204	81.799	.799
3	7	15	234	81.699	.799
3	7	15	304	81.699	.779
3	7	15	334	81.799	.839
3	7	15	404	81.599	.839
3	7	15	434	81.399	1.139
3	7	15	504	81.699	1.099
3	7	15	534	81.500	1.139
3	7	15	604	81.500	1.179
3	7	15	634	81.599	1.179
3	7	15	704	81.399	1.199
3	7	15	734	81.299	1.199
3	7	15	804	81.299	1.159
3	7	15	834	81.399	1.179
3	7	15	904	81.000	1.219
3	7	15	934	81.299	1.199
3	7	15	1004	81.299	1.119
3	7	15	1034	81.299	1.039
3	7	15	1104	81.199	1.079
3	7	15	1134	81.500	1.099
3	7	15	1204	81.500	1.199

Sta.	Mo.	Day	Time	Temp.	D.O.
3	7	15	1234	81.500	1.219
3	7	15	1304	81.590	1.340
3	7	15	1334	81.699	1.479
3	7	15	1404	81.500	1.179
3	7	15	1434	81.299	1.319
3	7	15	1504	81.699	1.979
3	7	15	1534	81.500	1.500
3	7	15	1604	81.899	2.139
3	7	15	1634	81.699	2.059
3	7	15	1704	81.500	1.799
3	7	15	1734	81.599	1.839
3	7	15	1804	81.500	1.739
3	7	15	1834	81.299	1.819
3	7	15	1904	81.400	1.830
3	7	15	1934	81.500	1.859
3	7	15	2004	81.500	2.019
3	7	15	2034	81.599	1.959
3	7	15	2104	81.599	2.479
3	7	15	2134	81.699	2.279
3	7	15	2204	81.500	2.199
3	7	15	2234	81.500	1.939
3	7	15	2304	81.500	1.779
3	7	15	2334	81.500	1.779
3	7	16	4	81.399	1.679
3	7	16	34	81.640	1.460
3	7	16	104	80.899	1.259
3	7	16	134	81.199	1.079
3	7	16	204	81.000	.979
3	7	16	234	81.199	1.179
3	7	16	304	81.099	1.179
3	7	16	334	80.899	1.059
3	7	16	404	80.899	1.179
3	7	16	434	81.000	1.179
3	7	16	504	80.899	1.319
3	7	16	534	81.099	1.459
3	7	16	604	80.799	1.439
3	7	16	634	80.699	1.479
3	7	16	704	80.699	1.439
3	7	16	734	80.699	1.439
3	7	16	804	80.699	1.539

Sta.	Mo.	Day	Time	Temp .	D.O.
3	7	16	834	80.699	1.559
3	7	16	904	80.699	1.579
3	7	16	934	80.699	1.539
3	7	16	1004	80.699	1.519
3	7	16	1034	80.899	1.839
3	7	16	1104	80.799	1.599
3	7	16	1134	80.899	2.039
3	7	16	1204	80.899	1.639
3	7	16	1234	81.299	2.059
3	7	16	1304	81.500	2.279
3	7	16	1334	81.500	1.839
3	7	16	1404	81.699	2.259
3	7	16	1434	81.899	2.539
3	7	16	1504	81.299	1.539
3	7	16	1534	81.899	2.239
3	7	16	1604	81.699	1.939
3	7	16	1634	81.500	1.779
3	7	16	1704	81.399	1.899
3	7	16	1734	82.099	2.239
3	7	16	1804	81.699	2.519
3	7	16	1834	82.099	3.000
3	7	16	1904	82.299	3.559
3	7	16	1934	81.799	2.939
3	7	16	2004	81.699	2.559
3	7	16	2034	81.699	2.699
3	7	16	2104	81.799	3.899
3	7	16	2134	81.699	2.899
3	7	16	2204	81.399	2.459
3	7	16	2234	81.500	3.539
3	7	16	2304	81.599	2.679
3	7	16	2334	81.399	2.339
3	7	17	4	81.399	2.139
3	7	17	34	81.299	1.839
3	7	17	104	81.399	1.799
3	7	17	134	81.199	1.699
3	7	17	204	81.099	1.779
3	7	17	234	81.199	1.559
3	7	17	304	81.199	1.479
3	7	17	334	80.899	1.519
3	7	17	404	80.899	1.339

Sta.	Mo.	Day	Time	Temp.	D.O.
3	7	17	434	80.899	1.459
3	7	17	504	80.899	1.699
3	7	17	534	80.899	1.379
3	7	17	604	81.099	1.439
3	7	17	634	81.000	1.539
3	7	17	704	80.799	1.559
3	7	17	734	80.899	1.519
3	7	17	804	80.899	1.539
3	7	17	834	80.899	1.599
3	7	17	904	80.799	1.679
3	7	17	934	80.699	1.659
3	7	17	1004	80.699	1.699
3	7	17	1034	80.899	1.759
3	7	17	1104	80.899	1.799
3	7	17	1134	80.699	1.859
3	7	17	1204	80.530	2.120
3	7	17	1234	80.360	2.390
3	7	17	1304	81.199	2.659
3	7	17	1334	81.500	2.559
3	7	17	1404	81.699	2.099
3	7	17	1434	81.699	2.379
3	7	17	1504	81.399	1.839
3	7	17	1534	81.500	1.779
3	7	17	1604	81.399	1.899
3	7	17	1634	81.399	1.559
3	7	17	1704	81.799	3.299
3	7	17	1734	80.799	2.099
3	7	17	1804	81.799	2.099
3	7	17	1834	81.599	1.939
3	7	17	1904	81.799	2.359
3	7	17	1934	81.599	2.079
3	7	17	2004	81.699	2.239
3	7	17	2034	81.500	2.099
3	7	17	2104	81.199	2.000
3	7	17	2134	81.199	2.059
3	7	17	2204	81.199	1.919
3	7	17	2234	81.399	6.079
3	7	17	2304	81.399	3.279
3	7	17	2334	81.199	2.239
3	7	18	4	81.199	1.859

Sta.	Mo.	Day	Time	Temp.	D.O.
3	7	18	34	81.199	1.839
3	7	18	104	81.399	1.659
3	7	18	134	81.099	1.659
3	7	18	204	81.099	1.519
3	7	18	234	81.199	1.399
3	7	18	304	81.000	1.339
3	7	18	334	81.199	1.319
3	7	18	404	81.199	1.239
3	7	18	434	81.000	1.259
3	7	18	504	80.899	1.199
3	7	18	534	80.799	1.199
3	7	18	604	81.000	1.159
3	7	18	634	80.899	1.299
3	7	18	704	81.199	1.279
3	7	18	734	80.699	1.419
3	7	18	804	80.799	1.459
3	7	18	834	80.799	1.459
3	7	18	904	80.899	1.500
3	7	18	934	80.899	1.539
3	7	18	1004	80.899	1.559
3	7	18	1034	80.699	1.559
3	7	18	1104	81.099	1.739
3	7	18	1134	81.199	1.599
3	7	18	1204	81.500	2.579
3	7	18	1234	81.099	1.639
3	7	18	1304	81.000	2.059
3	7	18	1334	81.500	2.219
3	7	18	1404	81.799	2.259
3	7	18	1434	81.799	2.299
3	7	18	1504	82.199	3.299
3	7	18	1541	81.899	2.279
3	7	18	1604	82.099	2.399
3	7	18	1634	81.799	2.199
3	7	18	1704	82.000	2.000
3	7	18	1734	82.000	2.039
3	7	18	1804	81.500	1.759
3	7	18	1834	81.599	1.639
3	7	18	1904	81.599	1.939
3	7	18	1934	81.699	1.899
3	7	18	2004	81.699	2.239

Sta.	No.	Day	Time	Temp.	D.O.
3	7	18	2034	81.500	2.099
3	7	18	2104	81.500	2.179
3	7	18	2134	81.399	1.979
3	7	18	2204	81.500	1.879
3	7	18	2234	81.399	1.819
3	7	18	2304	81.299	1.819
3	7	18	2334	81.599	4.759
3	7	19	4	81.699	4.379
3	7	19	34	81.299	2.079
3	7	19	104	81.199	1.719
3	7	19	134	80.899	1.719
3	7	19	204	81.199	1.759
3	7	19	234	80.899	1.639
3	7	19	304	81.199	1.639
3	7	19	334	81.199	1.579
3	7	19	404	81.000	1.559
3	7	19	434	80.899	1.399
3	7	19	504	81.099	1.299
3	7	19	534	80.990	1.280
3	7	19	604	80.899	1.279
3	7	19	634	81.000	1.339
3	7	19	704	81.000	1.339
3	7	19	734	81.099	1.439
3	7	19	804	81.099	1.459
3	7	19	834	80.899	1.599
3	7	19	904	81.000	1.559
3	7	19	934	81.199	1.619
3	7	19	1004	81.199	1.639
3	7	19	1034	81.399	1.839
3	7	19	1104	81.299	1.739
3	7	19	1134	81.199	2.059
3	7	19	1204	80.699	1.879
3	7	19	1234	81.299	2.599
3	7	19	1304	81.500	5.179
3	7	19	1334	80.699	2.039
3	7	19	1404	81.399	2.579
3	7	19	1434	80.699	1.939
3	7	19	1504	81.000	2.599
3	7	19	1534	81.899	4.199
3	7	19	1604	80.899	2.579

Sta.	Mo.	Day	Time	Temp.	D.O.
3	7	19	1634	81.199	2.539
3	7	19	1704	80.899	2.139
3	7	19	1734	81.199	2.339
3	7	19	1804	81.500	2.599
3	7	19	1834	80.899	2.439
3	7	19	1904	81.599	3.199
3	7	19	1934	81.099	2.299
3	7	19	2004	81.000	2.379
3	7	19	2034	80.899	2.199
3	7	19	2104	81.099	2.759
3	7	19	2134	80.799	2.359
3	7	19	2204	81.099	2.659
3	7	19	2234	80.799	2.399
3	7	19	2304	80.799	2.339
3	7	19	2334	80.899	2.259
3	7	20	4	80.699	2.179
3	7	20	34	81.000	4.399
3	7	20	104	81.000	3.099
3	7	20	134	80.899	2.859
3	7	20	204	80.699	2.000
3	7	20	234	80.799	2.979
3	7	20	304	80.699	2.019
3	7	20	334	80.599	1.979
3	7	20	404	80.500	1.919
3	7	20	434	80.399	1.859
3	7	20	504	80.399	1.759
3	7	20	534	80.399	1.719
3	7	20	604	80.699	1.739
3	7	20	634	80.500	1.699
3	7	20	704	80.699	1.699
3	7	20	734	80.399	1.739
3	7	20	804	80.699	1.679
3	7	20	834	80.699	2.099
3	7	20	904	80.500	2.239
3	7	20	934	81.199	2.659
3	7	20	1004	80.799	2.119
3	7	20	1034	80.799	1.979
3	7	20	1104	80.799	2.019
3	7	20	1134	81.399	2.639
3	7	20	1204	81.399	2.739

Sta.	Mo.	Day	Time	Temp.	D.O.
3	7	20	1234	81.799	2.739
3	7	20	1304	82.099	3.359
3	7	20	1334	82.099	3.879
3	7	20	1404	81.899	6.419
3	7	20	1434	82.000	4.059
3	7	20	1504	82.500	4.959
3	7	20	1534	82.199	3.759
3	7	20	1604	82.699	4.839
3	7	20	1634	82.500	5.139
3	7	20	1704	82.299	4.659
3	7	20	1734	81.799	3.179
3	7	20	1804	81.899	3.000
4	7	6	1306	79.699	1.899
4	7	6	1336	79.799	2.039
4	7	6	1406	79.500	1.899
4	7	6	1436	79.699	1.899
4	7	6	1506	79.599	1.819
4	7	6	1536	79.799	1.779
4	7	6	1606	79.799	1.919
4	7	6	1636	79.699	1.919
4	7	6	1706	79.799	2.059
4	7	6	1736	79.899	2.059
4	7	6	1806	79.899	2.079
4	7	6	1836	79.799	2.019
4	7	6	1906	79.799	2.079
4	7	6	1936	79.899	2.219
4	7	6	2006	79.699	2.039
4	7	6	2036	79.599	1.939
4	7	6	2106	79.599	2.059
4	7	6	2136	79.500	2.039
4	7	6	2206	79.399	2.000
4	7	6	2236	79.500	2.099
4	7	6	2306	79.500	2.119
4	7	6	2336	79.399	2.039
4	7	7	6	79.299	2.039
4	7	7	36	79.000	1.899
4	7	7	106	79.099	1.779
4	7	7	136	79.199	1.779
4	7	7	206	79.299	1.859
4	7	7	236	79.299	1.939

Sta.	Mo.	Day	Time	Temp.	D.O.
			306	79.299	1.859
4	7	7	336	79.199	1.799
4	7	7	406	79.000	1.839
4	7	7	436	79.199	1.779
4	7	7	506	79.299	1.839
4	7	7	536	79.199	1.799
4	7	7	606	78.899	1.779
4	7	7	636	78.899	1.799
4	7	7	706	79.199	1.779
4	7	7	736	79.199	1.839
4	7	7	806	79.199	1.899
4	7	7	836	79.099	1.839
4	7	7	906	79.399	2.219
4	7	7	936	79.500	1.959
4	7	7	1006	79.500	2.079
4	7	7	1036	79.699	2.139
4	7	7	1106	79.699	2.079
4	7	7	1136	79.500	2.159
4	7	7	1206	79.199	2.139
4	7	7	1236	79.299	2.299
4	7	7	1306	79.199	2.279
4	7	7	1336	79.299	2.339
4	7	7	1406	79.399	2.239
4	7	7	1436	79.799	2.639
4	7	7	1506	79.299	2.039
4	7	7	1536	79.500	2.000
4	7	7	1606	79.599	2.079
4	7	7	1636	79.699	1.939
4	7	7	1706	79.799	2.000
4	7	7	1736	79.799	2.079
4	7	7	1806	79.799	2.099
4	7	7	1836	79.699	2.119
4	7	7	1906	79.799	2.099
4	7	7	1936	79.799	2.139
4	7	7	2006	79.599	2.259
4	7	7	2036	79.500	2.299
4	7	7	2106	79.500	2.339
4	7	7	2136	79.399	2.299
4	7	7	2206	79.500	2.339
4	7	7	2236	79.500	2.299

Sta.	No.	Day	Time	Temp.	D.O.
4	7	7	2306	79.500	2.339
4	7	7	2336	79.099	2.379
4	7	8	6	79.199	2.279
4	7	8	36	78.899	2.279
4	7	8	106	79.099	2.379
4	7	8	136	78.899	2.399
4	7	8	206	78.899	2.359
4	7	8	236	78.899	2.299
4	7	8	306	78.699	2.199
4	7	8	336	78.699	2.179
4	7	8	406	78.899	2.079
4	7	8	436	78.899	2.099
4	7	8	506	78.899	2.079
4	7	8	536	78.899	2.079
4	7	8	606	78.899	2.059
4	7	8	636	78.799	1.959
4	7	8	706	78.799	2.000
4	7	8	736	78.899	2.059
4	7	8	806	78.899	2.099
4	7	8	836	79.099	2.139
4	7	8	906	78.899	2.199
4	7	8	936	78.899	2.559
4	7	8	1006	79.199	2.599
4	7	8	1036	78.899	2.439
4	7	8	1106	78.899	2.239
4	7	8	1136	78.899	2.219
4	7	8	1206	78.899	2.319
4	7	8	1236	78.699	2.399
4	7	8	1306	78.799	2.500
4	7	8	1336	78.699	2.579
4	7	8	1406	78.699	2.659
4	7	8	1436	78.699	2.619
4	7	8	1506	78.899	2.619
4	7	8	1536	78.799	2.739
4	7	8	1606	78.799	2.519
4	7	8	1636	78.899	2.399
4	7	8	1706	78.799	2.379
4	7	8	1736	78.899	2.179
4	7	8	1806	78.899	2.279
4	7	8	1836	78.899	2.279

Sta.	Mo.	Day	Time	. temp.	D.O.
4	7	8	1906	78.899	2.319
4	7	8	1936	79.000	2.259
4	7	8	2006	79.000	2.239
4	7	8	2036	78.899	2.219
4	7	8	2106	78.899	2.239
4	7	8	2136	78.899	2.219
4	7	8	2206	78.899	2.179
4	7	8	2236	78.799	2.219
4	7	8	2306	78.899	2.339
4	7	8	2336	78.899	2.379
4	7	9	6	78.699	2.399
4	7	9	36	78.699	2.379
4	7	9	106	78.699	2.439
4	7	9	136	78.799	2.359
4	7	9	206	78.699	2.299
4	7	9	236	78.699	2.239
4	7	9	306	78.799	2.199
4	7	9	336	78.599	2.079
4	7	9	406	78.500	2.079
4	7	9	436	78.500	2.099
4	7	9	506	78.699	2.019
4	7	9	536	78.699	1.939
4	7	9	606	78.599	1.879
4	7	9	636	78.500	1.839
4	7	9	706	78.299	1.859
4	7	9	736	78.399	1.879
4	7	9	806	78.399	1.899
4	7	9	836	78.599	1.899
4	7	9	906	78.699	1.899
4	7	9	936	78.699	1.899
4	7	9	1006	78.699	1.839
4	7	9	1036	78.899	2.019
4	7	9	1106	78.899	2.079
4	7	9	1136	79.000	2.219
4	7	9	1206	79.199	2.379
4	7	9	1236	79.299	2.579
4	7	9	1306	79.399	2.699
4	7	9	1336	79.500	2.839
4	7	9	1406	79.500	2.839
4	7	9	1436	79.899	2.839

Sta.	Mo.	Day	Time	Temp.	D.O.
4	7	9	1506	80.000	2.939
4	7	9	1536	80.299	3.339
4	7	9	1606	80.899	3.639
4	7	9	1636	79.899	2.739
4	7	9	1706	79.399	2.199
4	7	9	1736	79.699	2.239
4	7	9	1806	79.299	2.059
4	7	9	1836	79.399	2.139
4	7	9	1906	79.500	2.139
4	7	9	1936	79.500	2.159
4	7	9	2006	79.399	2.039
4	7	9	2036	79.199	1.959
4	7	9	2106	79.299	2.000
4	7	9	2136	79.299	2.179
4	7	9	2206	79.299	2.219
4	7	9	2236	79.399	2.279
4	7	9	2306	79.599	2.500
4	7	9	2336	79.500	2.379
4	7	10	6	79.500	2.479
4	7	10	36	79.500	2.479
4	7	10	106	79.500	2.399
4	7	10	136	79.500	2.299
4	7	10	206	79.500	2.439
4	7	10	236	79.299	2.539
4	7	10	306	79.399	2.579
4	7	10	336	79.500	2.539
4	7	10	406	79.199	2.500
4	7	10	436	79.299	2.399
4	7	10	506	79.099	2.099
4	7	10	536	79.000	2.039
4	7	10	606	78.899	2.059
4	7	10	636	79.000	1.919
4	7	10	706	79.099	2.059
4	7	10	736	79.199	2.119
4	7	10	806	79.199	2.099
4	7	10	836	79.199	2.099
4	7	10	906	79.299	2.000
4	7	10	936	79.599	2.259
4	7	10	1006	79.699	2.279
4	7	10	1036	79.699	2.439

Sta.	Mo.	Day	Time	Temp.	D.O.
4	7	10	1106	80.399	2.899
4	7	10	1136	81.199	3.879
4	7	10	1206	81.099	3.979
4	7	10	1236	80.899	3.919
4	7	10	1306	81.000	4.000
4	7	10	1336	81.399	3.859
4	7	10	1406	80.699	3.179
4	7	10	1436	81.500	3.879
4	7	10	1506	81.599	4.159
4	7	10	1536	81.699	4.199
4	7	10	1606	81.099	3.459
4	7	10	1636	81.000	3.439
4	7	10	1706	80.899	3.199
4	7	10	1736	80.599	2.939
4	7	10	1806	80.599	3.159
4	7	10	1836	80.799	3.319
4	7	10	1906	80.500	3.079
4	7	10	1936	80.299	3.179
4	7	10	2006	80.699	3.199
4	7	10	2036	80.399	3.079
4	7	10	2106	80.399	3.039
4	7	10	2136	80.399	3.039
4	7	10	2206	80.399	2.959
4	7	10	2236	80.299	2.899
4	7	10	2306	80.399	2.899
4	7	10	2336	80.099	3.119
4	7	11	6	80.399	3.159
4	7	11	36	80.199	3.079
4	7	11	106	80.199	2.979
4	7	11	136	80.199	3.000
4	7	11	206	80.199	2.979
4	7	11	236	80.199	3.039
4	7	11	306	80.399	3.239
4	7	11	336	80.299	3.199
4	7	11	406	80.399	3.139
4	7	11	436	80.399	3.119
4	7	11	506	80.399	3.079
4	7	11	536	80.299	3.000
4	7	11	606	80.399	3.039
4	7	11	636	79.899	2.739

Sta.	Mo.	Day	Time	Temp.	D.O.
4	7	11	706	80.099	2.719
4	7	11	736	80.000	2.739
4	7	11	806	80.000	2.779
4	7	11	836	80.000	2.780
4	7	11	906	80.000	2.799
4	7	11	936	80.199	3.059
4	7	11	1006	80.099	2.839
4	7	11	1036	80.299	3.000
4	7	11	1106	80.699	3.099
4	7	11	1136	80.899	3.139
4	7	11	1206	81.500	4.219
4	7	11	1236	81.500	4.299
4	7	11	1306	81.699	4.159
4	7	11	1336	82.199	4.219
4	7	11	1406	81.399	3.599
4	7	11	1436	82.299	4.479
4	7	11	1506	82.699	4.759
4	7	11	1536	82.799	4.719
4	7	11	1606	82.699	4.839
4	7	11	1636	82.099	4.659
4	7	11	1706	82.500	4.539
4	7	11	1736	82.000	4.359
4	7	11	1806	82.000	4.259
4	7	11	1836	81.299	3.879
4	7	11	1906	80.699	3.259
4	7	11	1936	80.599	3.279
4	7	11	2006	80.399	3.299
4	7	11	2036	80.399	3.279
4	7	11	2106	80.399	3.279
4	7	11	2136	80.399	3.179
4	7	11	2206	80.500	3.139
4	7	11	2236	80.500	3.099
4	7	11	2306	80.500	3.119
4	7	11	2336	80.599	3.179
4	7	12	6	80.399	3.119
4	7	12	36	80.500	3.179
4	7	12	106	80.500	3.179
4	7	12	136	80.500	3.259
4	7	12	206	80.799	3.339
4	7	12	236	80.799	3.359

Sta.	Mo.	Day	Time	Temp.	D.O.
4	7	12	306	81.000	3.339
4	7	12	336	80.899	3.379
4	7	12	406	81.000	3.379
4	7	12	436	80.899	3.339
4	7	12	506	80.899	3.339
4	7	12	536	81.299	3.339
4	7	12	606	80.899	3.299
4	7	12	636	81.099	3.319
4	7	12	706	80.899	3.339
4	7	12	736	80.899	3.279
4	7	12	806	80.399	3.059
4	7	12	836	80.299	2.979
4	7	12	906	80.399	3.039
4	7	12	936	80.500	3.000
4	7	12	1006	80.599	3.439
4	7	12	1036	77.899	3.279
4	7	12	1106	77.899	5.059
4	7	12	1136	78.000	5.000
4	7	12	1206	78.199	5.379
4	7	12	1236	79.199	6.159
4	7	12	1306	79.299	6.699
4	7	12	1336	79.699	6.899
4	7	12	1406	79.890	6.990
4	7	12	1436	80.099	7.099
4	7	12	1506	80.099	7.179
4	7	12	1536	80.000	6.659
4	7	12	1606	80.199	6.619
4	7	12	1636	80.000	6.800
4	7	12	1706	79.500	7.100
4	7	12	1736	79.000	7.400
4	7	12	1806	78.700	7.700
4	7	12	1836	78.300	8.000
4	7	12	1906	78.000	8.250
4	7	12	1936	77.800	8.500
4	7	12	2006	77.599	8.739
4	7	12	2036	78.099	8.379
4	7	12	2106	78.199	8.299
4	7	12	2136	78.199	8.000
4	7	12	2206	78.199	7.879
4	7	12	2236	78.299	7.779

Sta.	Mo.	Day	Time	Temp.	D.O.
4	7	12	2306	78.199	7.659
4	7	12	2336	78.399	7.879
4	7	13	6	78.299	7.619
4	7	13	36	78.500	7.500
4	7	13	106	78.399	7.379
4	7	13	136	78.500	7.359
4	7	13	206	78.399	7.319
4	7	13	236	78.399	7.199
4	7	13	306	78.399	6.899
4	7	13	336	78.399	6.739
4	7	13	406	78.699	6.699
4	7	13	436	78.699	6.759
4	7	13	506	78.599	6.659
4	7	13	536	78.799	6.619
4	7	13	606	78.699	6.339
4	7	13	636	78.899	6.259
4	7	13	706	78.899	6.179
4	7	13	736	78.799	6.379
4	7	13	806	78.699	6.399
4	7	13	836	78.490	6.450
4	7	13	906	78.299	6.539
4	7	13	936	78.199	6.599
4	7	13	1006	78.240	6.790
4	7	13	1036	78.290	7.050
4	7	13	1106	78.340	7.300
4	7	13	1136	78.399	7.479
4	7	13	1206	78.399	7.399
4	7	13	1236	78.500	7.359
4	7	13	1306	78.650	7.370
4	7	13	1336	78.799	7.399
4	7	13	1406	79.299	8.959
4	7	13	1436	79.500	8.559
4	7	13	1506	79.399	8.339
4	7	13	1536	79.699	8.879
4	7	13	1606	79.699	8.439
4	7	13	1636	79.500	8.079
4	7	13	1706	79.699	7.679
4	7	13	1736	79.599	7.859
4	7	13	1806	79.699	8.079
4	7	13	1836	79.599	8.099

Sta.	Mo.	Day	Time	Temp.	D.O.
4	7	13	1906	79.599	7.879
4	7	13	1936	79.299	6.739
4	7	13	2006	79.000	7.279
4	7	13	2036	78.699	6.059
4	7	13	2106	78.500	7.079
4	7	13	2136	78.500	7.110
4	7	13	2206	78.500	7.159
4	7	13	2236	78.299	6.899
4	7	13	2306	78.500	7.179
4	7	13	2336	78.399	7.000
4	7	14	6	78.399	6.579
4	7	14	36	78.399	6.500
4	7	14	106	78.199	6.539
4	7	14	136	78.199	6.319
4	7	14	206	78.399	6.199
4	7	14	236	78.399	6.000
4	7	14	306	78.199	5.839
4	7	14	336	78.199	5.699
4	7	14	406	78.399	5.699
4	7	14	436	78.299	5.559
4	7	14	506	78.399	5.479
4	7	14	536	78.399	5.299
4	7	14	606	78.500	5.259
4	7	14	636	78.699	5.139
4	7	14	706	78.500	5.899
4	7	14	736	78.699	4.959
4	7	14	806	78.599	4.979
4	7	14	836	78.599	5.419
4	7	14	906	78.599	5.439
4	7	14	936	78.799	5.759
4	7	14	1006	78.899	6.979
4	7	14	1036	78.799	7.099
4	7	14	1106	78.699	7.159
4	7	14	1136	78.599	6.859
4	7	14	1206	78.500	6.839
4	7	14	1236	78.699	6.919
4	7	14	1306	78.699	6.759
4	7	14	1336	78.599	6.359
4	7	14	1406	78.500	5.719
4	7	14	1436	78.399	5.739

Sta.	No.	Day	Time	Temp.	D.O.
4	7	14	1506	78.500	6.159
4	7	14	1536	78.670	5.950
4	7	14	1606	78.699	5.759
4	7	14	1636	78.699	5.679
4	7	14	1706	78.899	5.939
4	7	14	1736	78.899	8.439
4	7	14	1806	78.799	5.699
4	7	14	1836	78.799	5.779
4	7	14	1906	78.899	5.599
4	7	14	1936	78.899	5.000
4	7	14	2006	78.699	5.079
4	7	14	2036	78.699	5.459
4	7	14	2106	78.500	5.159
4	7	14	2136	78.399	5.000
4	7	14	2206	78.199	5.219
4	7	14	2236	78.099	4.979
4	7	14	2306	78.000	6.979
4	7	14	2336	77.899	4.939
4	7	15	6	77.899	4.919
4	7	15	36	77.699	4.919
4	7	15	106	77.699	4.899
4	7	15	136	77.699	4.819
4	7	15	206	77.500	4.739
4	7	15	236	77.899	4.799
4	7	15	306	77.899	4.779
4	7	15	336	77.799	4.779
4	7	15	406	77.899	4.559
4	7	15	136	77.699	4.819
4	7	15	206	77.500	4.739
4	7	15	236	77.899	4.799
4	7	15	306	77.899	4.779
4	7	15	336	77.799	4.779
4	7	15	406	77.899	4.559
4	7	15	436	78.099	4.559
4	7	15	506	78.000	4.339
4	7	15	536	78.000	4.259
4	7	15	606	78.000	4.119
4	7	15	636	78.199	4.179
4	7	15	706	78.000	4.179
4	7	15	736	77.899	4.179

Sta.	Mo.	Day	Time	Temp.	D.O.
4	7	15	806	78.099	4.079
4	7	15	836	78.000	4.000
4	7	15	906	77.500	4.219
4	7	15	936	77.899	4.339
4	7	15	1006	77.899	4.419
4	7	15	1036	78.000	4.419
4	7	15	1106	77.899	4.699
4	7	15	1136	78.099	5.219
4	7	15	1206	78.000	5.719
4	7	15	1236	78.000	5.719
4	7	15	1306	78.099	5.679
4	7	15	1336	78.299	5.939
4	7	15	1406	89.199	6.639
4	7	15	1436	78.299	6.939
4	7	15	1506	78.399	6.919
4	7	15	1536	78.299	6.039
4	7	15	1606	78.399	6.179
4	7	15	1636	78.299	5.899
4	7	15	1706	78.299	5.939
4	7	15	1736	78.500	6.039
4	7	15	1806	78.399	5.739
4	7	15	1836	78.399	5.879
4	7	15	1906	78.199	6.199
4	7	15	1936	78.199	5.959
4	7	15	2006	78.199	5.959
4	7	15	2036	78.000	5.979
4	7	15	2106	77.899	6.099
4	7	15	2136	78.000	5.579
4	7	15	2206	77.899	5.899
4	7	15	1936	78.199	5.959
4	7	15	2006	78.199	5.959
4	7	15	2036	78.000	5.979
4	7	15	2106	77.899	6.099
4	7	15	2136	78.000	5.579
4	7	15	2206	77.899	5.899
4	7	15	2236	77.899	5.239
4	7	16	706	77.199	4.619
4	7	16	736	77.099	4.779
4	7	16	806	77.199	4.619
4	7	16	836	77.000	4.479

Sta.	Mo.	Day	Time	Temp.	D.O.
4	7	16	906	77.099	4.179
4	7	16	936	77.399	3.659
4	7	16	1006	77.599	3.500
4	7	16	1036	77.599	4.339
4	7	16	1106	77.299	5.159
4	7	16	1136	77.599	5.739
4	7	16	1206	78.099	6.519
4	7	16	1236	77.699	5.399
4	7	16	1306	77.799	5.259
4	7	16	1336	77.699	5.139
4	7	16	1406	77.699	4.699
4	7	16	1436	77.799	4.699
4	7	16	1506	77.699	4.279
4	7	16	1536	77.799	4.179
4	7	16	1606	77.899	4.839
4	7	16	1636	78.899	7.659
4	7	16	1706	78.199	5.359
4	7	16	1736	79.699	8.399
4	7	16	1806	79.500	8.059
4	7	16	1836	79.000	6.579
4	7	16	1906	78.199	5.779
4	7	16	1936	78.199	5.179
4	7	16	2006	78.299	5.579
4	7	16	2036	78.399	6.119
4	7	16	2106	78.399	6.019
4	7	16	2136	78.099	5.500
4	7	16	2206	78.199	4.979
4	7	16	2236	77.500	4.299
4	7	16	2306	77.000	3.799
4	7	16	2336	77.299	3.879
4	7	17	6	77.099	4.359
4	7	17	36	77.299	4.539
4	7	17	106	77.199	4.859
4	7	17	136	77.599	4.939
4	7	17	206	77.599	5.059
4	7	17	236	77.199	5.159
4	7	17	306	77.500	5.000
4	7	17	336	77.399	4.359
4	7	17	406	77.500	4.239
4	7	17	436	77.399	4.099

Sta.	Mo.	Day	Time	Temp.	D.O.
4	7	17	506	77.299	4.179
4	7	17	536	77.399	4.159
4	7	17	606	77.399	4.179
4	7	17	636	77.199	4.339
4	7	17	706	77.199	4.359
4	7	17	736	77.199	4.059
4	7	17	806	77.299	3.979
4	7	17	836	77.199	4.039
4	7	17	906	77.399	4.019
4	7	17	936	77.399	4.179
4	7	17	1006	77.500	4.359
4	7	17	1036	77.899	4.419
4	7	17	1106	77.799	4.539
4	7	17	1136	77.699	4.759
4	7	17	1206	77.790	5.250
4	7	17	1236	77.899	5.719
4	7	17	1306	77.899	5.359
4	7	17	1336	77.699	4.859
4	7	17	1406	77.799	5.159
4	7	17	1436	77.799	4.879
4	7	17	1506	77.799	4.479
4	7	17	1536	77.899	4.259
4	7	17	1606	77.799	4.099
4	7	17	1636	77.899	4.000
4	7	17	1706	77.699	3.679
4	7	17	1736	77.699	3.839
4	7	17	1806	77.799	4.279
4	7	17	1836	78.099	5.279
4	7	17	1906	78.099	5.119
4	7	17	1936	78.299	5.639
4	7	17	2006	78.199	5.219
4	7	17	2036	78.199	5.279
4	7	17	2106	78.399	5.439
4	7	17	2136	78.399	5.379
4	7	17	2206	78.299	5.319
4	7	17	2236	78.299	5.199
4	7	17	2306	78.099	5.179
4	7	17	2336	78.199	4.739
4	7	18	6	77.799	4.119
4	7	18	36	77.399	3.699

Sta.	Mo.	Day	Time	Temp.	D.O.
4	7	18	106	77.299	3.639
4	7	18	136	77.299	3.500
4	7	18	206	77.299	3.539
4	7	18	236	77.299	3.699
4	7	18	306	77.299	3.659
4	7	18	336	77.199	3.819
4	7	18	406	77.299	3.639
4	7	18	436	77.299	3.699
4	7	18	506	77.399	3.599
4	7	18	536	77.399	3.699
4	7	18	606	77.199	3.679
4	7	18	636	77.299	3.539
4	7	18	706	77.399	3.599
4	7	18	736	77.399	3.679
4	7	18	806	77.699	3.839
4	7	18	836	77.799	4.000
4	7	18	906	77.799	4.139
4	7	18	936	78.000	4.159
4	7	18	1006	77.899	4.219
4	7	18	1036	77.899	4.179
4	7	18	1106	77.899	4.179
4	7	18	1136	78.199	4.039
4	7	18	1206	78.199	4.719
4	7	18	1236	78.500	5.019
4	7	18	1306	78.199	4.039
4	7	18	1336	78.000	5.079
4	7	18	1406	79.500	6.659
4	7	18	1436	78.399	5.199
4	7	18	1506	78.199	4.859
4	7	18	1543	77.899	4.599
4	7	18	1606	78.099	4.619
4	7	18	1636	78.000	4.459
4	7	18	1706	78.099	4.419
4	7	18	1736	78.099	4.179
4	7	18	1806	78.000	3.419
4	7	18	1836	77.799	3.539
4	7	18	1906	77.699	4.159
4	7	18	1936	78.399	5.979
4	7	18	2006	78.199	5.359
4	7	18	2036	78.299	5.199

Sta.	Mo.	Day	Time	Temp.	D.O.
4	7	18	2106	78.199	5.079
4	7	18	2136	78.399	5.219
4	7	18	2206	78.199	5.079
4	7	18	2236	78.399	5.179
4	7	18	2306	78.399	5.179
4	7	18	2336	78.299	5.159
4	7	19	6	78.299	5.199
4	7	19	36	78.299	5.139
4	7	19	106	78.099	4.500
4	7	19	136	77.699	4.000
4	7	19	206	77.699	3.959
4	7	19	236	77.599	3.839
4	7	19	306	77.399	3.639
4	7	19	336	77.099	3.679
4	7	19	406	77.500	4.000
4	7	19	436	77.199	3.459
4	7	19	506	77.299	3.819
4	7	19	536	77.399	3.899
4	7	19	606	77.500	3.979
4	7	19	636	77.299	4.000
4	7	19	706	77.500	4.000
4	7	19	736	77.599	4.339
4	7	19	806	77.699	4.079
4	7	19	836	77.799	4.199
4	7	19	906	77.899	4.439
4	7	19	936	78.099	4.739
4	7	19	1006	78.099	4.739
4	7	19	1036	78.399	5.139
4	7	19	1106	78.199	4.979
4	7	19	1136	78.399	5.039
4	7	19	1206	78.099	5.039
4	7	19	1236	78.399	5.179
4	7	19	1306	78.500	5.239
4	7	19	1336	78.699	5.859
4	7	19	1406	78.399	4.719
4	7	19	1436	78.299	5.099
4	7	19	1506	78.500	5.199
4	7	19	1536	78.399	4.939
4	7	19	1606	78.299	5.000
4	7	19	1636	78.399	4.979

Sta.	Mo.	Day	Time	Temp.	D.O.
4	7	19	1706	78.699	5.500
4	7	19	1736	78.699	6.199
4	7	19	1806	78.500	4.599
4	7	19	1836	78.399	4.279
4	7	19	1906	78.299	4.179
4	7	19	1936	78.299	3.939
4	7	19	2006	78.299	4.619
4	7	19	2036	78.899	5.839
4	7	19	2106	78.699	5.439
4	7	19	2136	78.500	4.859
4	7	19	2206	78.699	5.699
4	7	19	2236	78.500	5.539
4	7	19	2306	78.599	5.639
4	7	19	2336	78.500	5.699
4	7	20	6	78.500	5.639
4	7	20	36	78.399	5.639
4	7	20	106	78.500	5.579
4	7	20	136	78.399	5.179
4	7	20	206	78.099	4.619
4	7	20	236	78.000	3.739
4	7	20	306	77.699	4.459
4	7	20	336	77.599	3.719
4	7	20	406	77.599	3.500
4	7	20	436	77.699	3.639
4	7	20	506	77.799	3.739
4	7	20	536	77.699	3.779
4	7	20	606	77.699	3.779
4	7	20	636	77.799	3.839
4	7	20	706	77.699	3.819
4	7	20	736	77.899	4.079
4	7	20	806	77.699	4.079
4	7	20	836	77.899	4.179
4	7	20	906	78.199	4.719
4	7	20	936	78.299	4.779
4	7	20	1006	78.699	5.139
4	7	20	1036	78.899	5.479
4	7	20	1106	79.099	5.779
4	7	20	1136	79.199	5.939
4	7	20	1206	79.500	6.299
4	7	20	1236	79.799	6.699

Sta.	Mo.	Day	Time	Temp.	D.O.
4	7	20	1306	79.799	7.039
4	7	20	1336	79.899	7.139
4	7	20	1406	79.799	6.939
4	7	20	1436	78.899	5.619
4	7	20	1506	79.399	6.279
4	7	20	1536	79.099	6.459
4	7	20	1606	78.799	5.359
4	7	20	1636	78.899	5.539
4	7	20	1706	78.699	5.279
4	7	20	1736	78.500	5.159
4	7	20	1806	78.399	4.959

1	Accession Number	2	Subject Field & Group	SELECTED WATER RESOURCES ABSTRACTS INPUT TRANSACTION FORM
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5 Organization
Stochastics Incorporated, Blacksburg, Virginia

6 Title
STOCHASTIC MODELING FOR WATER QUALITY MANAGEMENT

10	Author(s)	11	Date	12	Pages	15	Contract Number
	Krutchkoff, Richard G.		1971		395		14-12-849
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Biochemical oxygen demand, Dissolved Oxygen, streams,
Mathematical models

25 Identifiers (Starred First)
*Stochastic models, Segmented model, Random inputs, Potomac, Ohio

27 Abstract
The purpose of this work was to extend previous stochastic models and to verify this extension. In particular there were four tasks undertaken: a) to adapt the model to accept variable or random input loads, b) to adapt the estuary model to treat segmented estuaries, c) to verify the adapted model with data supplied by WQO, d) to find a method for using data to estimate and predict the stochastic parameter Δ . The four tasks were successfully completed. Verification was done with data from the Ohio River and the Potomac Estuary. This report was submitted in fulfillment of project number 16090DUH, contract number 14-12-849 under the sponsorship of the Water Quality Office of the Environmental Protection Agency. (Krutchkoff, VPI&SU)

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